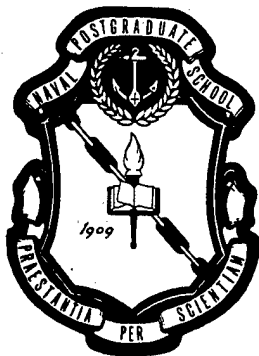


Naval Postgraduate School
Monterey, California 93943-5138



SUMMARY OF RESEARCH 1996

Department of Computer Science

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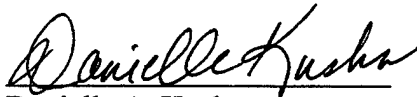
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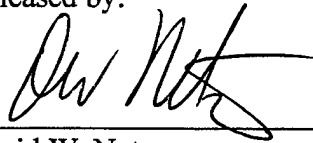
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This report contains summaries of research projects in the Department of Computer Science. A list of recent publications is also included which consists of conference presentations and publications, books, contributions to books, published journal papers, technical reports, and thesis abstracts.

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**DEPARTMENT OF
COMPUTER SCIENCE**

TED G. LEWIS
CHAIR

THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to increase the combat effectiveness of US and Allied armed forces and enhance the security of the USA through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense-related challenges.



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Preface

Research is an integral part of graduate education. At the Naval Postgraduate School (NPS), the goals of research are to:

- Provide a meaningful, high quality, capstone learning experience for our students.
- Keep faculty on the leading edge of advances in defense-related science, technology, management and policy to ensure that the latest information is incorporated into NPS courses and curricula.
- Apply faculty and student knowledge to enhance DoN/DoD operational effectiveness.

Pursuit of these goals increases the technical and managerial capability of the officer corps to keep pace with an increasingly complex defense posture in today's world.

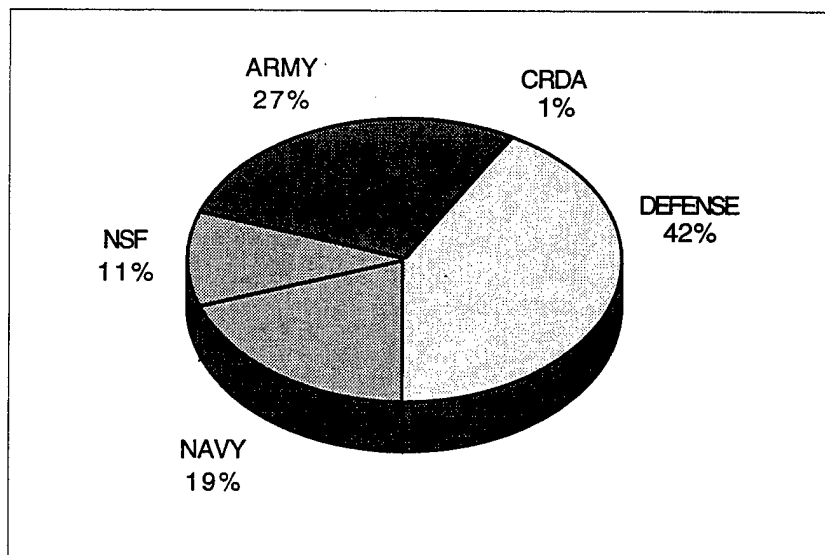
New technologies and policy changes will of course occur, necessitating changes in educational programs and stronger ties between the fleet and the support establishment. NPS must remain poised to face this challenge and to utilize emerging technologies and new policies within its curricula programs. Faculty, therefore, must stay abreast of these developments through a dynamic research program that helps fulfill the School's goals of excellence, uniqueness, and relevance.

The overall research program at NPS has three funded components. The Direct Funded Research and Institute for Joint Warfare Analysis Programs are institutionally funded within the School's operating budget. The Direct Funded Research Program is administered by the Associate Provost and Dean of Research. The Institute for Joint Warfare Analysis Program is administered by the Director of IJWA.

- The Direct Funded Research (DFR) Program provides funding to stimulate innovative research ideas of benefit to the DoN and may be used for cost-sharing with reimbursable research efforts. This funding ensures, in particular, that all Navy-sponsored NPS curricula are equitably supported, that new faculty are provided an opportunity to establish a research program of importance to DoN/DoD and other national security interests, and that faculty and students from across the campus are encouraged to interact with one another.
- The Institute for Joint Warfare Analysis Research Program provides funding to stimulate innovative research ideas with a strong emphasis on joint, interdisciplinary areas. This funding ensures that joint relevance is a consideration of faculty research.
- The Reimbursable Research (RR) Program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policy makers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. This ensures that NPS research remains highly regarded by academic peers and government officials and fosters a closer relationship between NPS and other outside organizations.

The three research programs are complementary and ensure that the overall research program is flexible, responsive, balanced and supportive of the unique needs of the military.

In 1996, the level of the research effort at the Naval Postgraduate School was 141 faculty workyears and exceeded 29 million dollars. Eighty percent of the research was funded by reimbursable sponsors and 20 percent was funded by the Naval Postgraduate School. Sixty-five percent of the work was performed for the Navy and the remainder was sponsored by other agencies, both DoD and non-DoD. A profile of the reimbursable program of the Department of Computer Science is provided in Figure 1:



Size of Program: \$2,779K

Figure 1. Department of Computer Science - Sponsor Profile

Research at NPS is carried out by faculty in the School's eleven Academic Departments, four Interdisciplinary Groups and the School of Aviation Safety. In the pages that follow, research summaries are provided for projects undertaken by faculty in the Department of Computer Science during 1996. An overview and faculty listing are provided as an introduction. A list of publications is also included, if applicable. Abstracts for thesis advised by department faculty in 1996 complete this research summary.

Questions about particular projects may be directed to the Faculty Principal Investigator listed, the Department/Group Chair, or the Department Associate Chair for Research. Questions may also be directed to the Research Office. General questions about the NPS Research Program should be directed to the Research Office at (408) 656-2098 (voice) or research@nps.navy.mil (e-mail).

August 1997

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DEPARTMENT SUMMARY

The Department of Computer Science has active research in several important areas of interest to Department of the Navy. A description of the major areas follows.

Software Engineering

Professor Luqi's research is to enable rapid prototyping of hard real-time systems via a Computer-Aided Prototyping System (CAPS). CAPS is based on a prototyping language with module specifications for modeling real-time systems and combining reusable software. These tools make it possible for prototypes to be designed quickly and executed to validate the requirements. The research focuses on automated methods for retrieving, adapting, and combining reusable components based on normalized module specifications; establishing feasibility of real-time constraints via scheduling algorithms; simulating unavailable components via algebraic specifications; automatically generating translators and real-time schedules for supporting execution; constructing a prototyping project database using derived mathematical models; providing automated design completion and error checking facilities in a designer interface; and establishing a convenient graphical interface for design and debugging.

Rapid prototyping is a means for stabilizing and validating the requirements for complex systems by helping customers visualize system behavior prior to detailed implementation, e.g., for embedded control systems with hard real-time constraints. CAPS supports an iterative prototyping process characterized by exploratory design and extensive prototype evolution. This should enable the first production version of the software to match user needs and reduce the need for expensive modifications after delivery. The current version of CAPS has been used to generate a software prototype of a C3I system with hard real-time constraints. The preliminary result of such an approach has shown great promise.

The major objective of Professor Shing's research is to develop efficient algorithms and tools to support the computer-aided rapid prototyping of real-time embedded systems. The process of design and development of real-time embedded systems is often plagued with uncertainty, ambiguity and inconsistency. The timing requirements are difficult for the user to provide and for the analysts to determine. It is also very difficult to determine whether a delivered system meets its requirements. Rapid prototyping provides a means to alleviate the risks and difficulties in real-time embedded systems.

Specific topics Professor Shing is investigating include efficient heuristic scheduling algorithms for real-time systems, and incremental attribute-evaluation and software architectures for distributed real-time embedded systems.

Formal methods and associated automated decision aids have a large potential for practical impact that has not been fully realized. To help bring this about, Professor Berzins has developed a formal specification language specifically designed for large scale applications that include parallel, distributed, and real-time systems. He is currently investigating a variety of methods and tools for partially automating many aspects of software development.

Professor Berzins seeks to develop fundamental theory and practical methods for combining several changes to a software system with mathematically provable guarantees of correctness. The main goal of this research effort is to enable a higher level of computer-aided design in development and maintenance of large software systems. Combining changes to software is a fundamental problem in software engineering. This process is important in all phases of developing large software systems, where multiple changes must be developed concurrently and then combined. This work has potential applications to software maintenance, view integration in specifications, version control in design databases, and multiple inheritance in specification or programming languages.

Professor Berzins has also investigated change merging for specifications and for software prototypes of real-time systems. He integrated a change merging mechanism for specifications with an inheritance mechanism and investigated both applications and formal properties of the resulting structure. He has been working on an analog of the program slicing method for the PSDL language. PSDL presents new problems because it includes explicit real-time constraints and parallel operations. He has also designed an automated design management and job assignment system. The main advance provided by this system is automated scheduling and job assignment for teams of engineers in an environment where plans are uncertain, partially known, and subject to change while the work is in progress.

As attempts are made to automate the software development process through rapid prototyping and other means, there is an increasing need for new forms of automated analyses of specifications and code. These analyses can provide useful information about functionality and behavior that can aid in the software design process. The goal of Professor Volpano's Advanced Type Systems Project at NPS is to develop new forms of static analyses within the well-understood context of type systems.

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There are two major research thrusts in the project. One involves developing the type-theoretic foundation for sound polymorphic typing in the popular imperative programming languages C. A sound type system for a polymorphic dialect of K&R C has been developed. It is very well known that getting soundness in the context of polymorphism and pointers, or references, is difficult. The system was proved sound with respect to a natural semantics for core C. The type system of Edinburgh LCF ML was also proved sound. Although widely conjectured to be sound, its soundness actually remained an open problem for almost 20 years.

Professor Shimeall's interests center around a consistent view of the analysis of software. During the development of software there are a variety of properties that must be applied and validated to the software, including correctness, safety, security, and modifiability. While these properties are very diverse, there are a set of approaches that are shared in the validation of these processes.

Professor Shimeall's research has identified three basic approaches to the analysis of software with respect to the above properties: similarity, individuality and source-affinity. Tools have been constructed to apply these approaches to software: Similarity: Reacher - reachability condition analyzer; Falter - activation condition annotator; Spacer - propagation condition analyzer; Viewer - user interface to the similarity toolset; Individuality: FTE - fault/event tree graphical editor; FT2PN - fault tree/Petri net converter; PN2FT - Petri net/fault tree converter; ACTT - Ada/fault tree converter; Source-affinity: Tparse/An - variable-initialization analyzer; AAPSLC - Ada physical source line counter. Taken together, these tools provide a flexible framework for addressing the analysis of a variety of software properties, and they have been applied to several systems to examine correctness, safety and modifiability concerns. Work in progress includes extending the functionality of these tools, adding additional tools to automate other analysis phases and applying these tools to security and other software properties.

Computer Graphics and Visualization

The NPSNET Research Group is a group of faculty (headed by Professors Zyda and Pratt), staff, and students that work in all areas of networked virtual environments. The research group is currently focused on the following virtual environment (VE) research topics: the large-scale networking of virtual environments (environments greater than 1,000 players), VE network applications protocols, rapidly reconfigurable VE network protocols, Distributed Interactive Simulation (DIS) and High-Level Architecture (HLA) protocols, the real-time walkthrough of large-scale networked VEs, world modeling software for managing large scale networked VEs, the instrumentation of the human body and its representation in the networked VE, hypermedia integration (how we place video, audio, imagery and textual data in the networked VE), and geometric modeling (terrain, building and other object modeling).

The NPSNET Research Group's efforts focus on the development of the above software areas and the integration of proven components of that work into a core software system, NPSNET. NPSNET is currently capable of simulating articulated humans, and ground, air and sea-going vessels in the DIS networked virtual environment. NPSNET can support about 250-300 players using currently available networking and workstation technology. NPSNET is the first 3D virtual environment that is capable of playing across the multicast backbone (MBONE) of the Internet.

Real-time (3D) computer graphics workstations have progressed to a point where they can be used for Out The Window (OTW) visual simulation systems. The key to the development of these systems is the underlying software. As with most leading edge technologies, the construction of the required software is a black art. As such, the focus of the research has been the development, documentation, and distribution of workstation based OTW visual display systems. A major component of this research is the distribution of the simulation across the network. This allows multiple users to interact with each other in a virtual environment. This is one of the key premises of DIS, inserting humans into the virtual environment where they can "free-play" different scenarios. While this sounds simple, the problems of networks, human/computer interfaces, and data management are significant research topics. While the humans in the virtual environment comprise an integral component of the system, there are not enough manned simulators to sufficiently populate the world.

To provide the additional entities, Professor Pratt is conducting research in the use of traditional constructive combat models and autonomous agents to populate the world. By providing an interface to the traditional models, the work that has been done before in combat modeling can be leveraged. This, combined with the research on autonomous agents, provides a mechanism to provide friendly and opposing forces to complement the manned simulators.

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While virtual environments (VE) are gaining widespread notoriety as a training tool and general interface to information spaces, little research has been done to show that this technology is in fact useful for training or that it represents an improved interface over conventional techniques.

One of the fundamental obstacles involved with large information spaces and most VE simulators is that of user disorientation. Users cannot navigate a virtual space as well as they can a real space. Professor Darken's interests in this problem come from two different perspectives: (1) navigation aids to improve users' performance on navigation tasks in VEs, and (2) navigation training aids to improve users' performance on real world navigation tasks trained in the VE. Another aspect of this problem has to do with locomotion techniques available to users. Currently, there is no way for a user to walk naturally in a large VE. There are encumbering cables and limited space in which the user must operate. We have recently evaluated a device (the Omni-Directional Treadmill) that attempts to overcome this limitation.

It has recently been shown that we receive more information aurally than we are consciously aware of. In fact, it is believed that sound has a large impact on training effectiveness in VEs. Professor Darken is beginning a research program to investigate this issue within the context of air training. In this, "the information age," it is somewhat surprising that we allow ourselves to be chained to a desk, staring at a monitor and typing on a keyboard. Professor Darken believes usability in computing is not just a matter of how we do things with computers but where we do things with computers. The objective here is to develop a wireless mobile computing environment where information is where users need it when they need it. There is a strong overlap between this and VE research as what we learn about usable interfaces to virtual spaces can be applied to building usable interfaces to real spaces such as ship compartments, buildings, towns, and the battlefield.

One of the key components of a military virtual environment is the geometric description of the terrain database. To address the importance of the terrain database, NPSNET has active research projects in the areas of terrain modifications, culling, and polygon reduction. NPS is quickly becoming one of the leading organizations within DoD for the understanding and conversion of terrain database formats.

Research for the development of highly realistic tactical battlefield simulation systems by Professor Baer is organized around three main areas. These are: (1) development of algorithms for visualizing realistic battlefield effects including 1 meter or better terrain backgrounds, photo realistic targets, and environmental effects and battlefield; obscuration, (2) development of database generation and update systems designed to reduce instrumentation, photographic, and video data to object-descriptor data bases, and (3) development of high speed low cost parallel-processor technologies in order to execute the algorithms and systems resulting from the two previous research areas.

Artificial Intelligence and Robotics

The major objective of Professor Kanayama's research is to investigate fundamental theories in autonomous mobile robotics. Since autonomous self-contained robots have complete freedom in motion, the topic is fundamentally interesting in robotics and AI. Furthermore, there are tremendous opportunities for such robots to perform practical tasks in the real world. Professor Kanayama tests and evaluates theories on the Autonomous Indoor Mobile Robot Yamabico-11. Research activities cover abstract mathematical models, intelligent algorithm finding, software development, and hardware construction. Specific topics Professor Kanayama has been investigating include: a smooth vehicle tracking algorithm, sonar interpretation, rigid body motion planning, automated cartography, vehicle control by a steering function, a high-level mobile robot language MML, a real-time hardware/software architecture for mobile robots, motion planning for an autonomous underwater vehicle, and fast gait planning for an underwater walking robot.

The role of robotics in manufacturing is already well established and is an important factor in increasing industrial productivity. In contrast, the introduction of robots into military operations has just begun. This is due in part to justifiable concerns about removing human control from potentially lethal systems, but perhaps to a greater extent is the result of the relatively weak capabilities of mobile robots operating in the unstructured or even hostile environments typical of military situations. Professor McGhee's research is concerned with adapting existing robot technology to suit military applications, and with making theoretical and engineering advances in areas where current knowledge is inadequate for a selected application. He pursues this goal both through the construction of prototype systems for concept demonstration, and by means of real-time graphical dynamic simulation studies in support of such research.

With the recent rapid increase in interest in networked interactive simulations as an alternative to actual field exercises, the accurate modeling of vehicle dynamics needed for mobile robot design studies has taken on a new and larger

DEPARTMENT SUMMARY

urgency. At present, Professor McGhee's research is centered around the application of unmanned submersibles to mine countermeasures. Both swimming vehicles and walking vehicles are being considered for this purpose. In the first instance, the NPS Autonomous Underwater Vehicle (AUV) is available for experimental studies. In the second, various vehicles derived from his earlier research on terrestrial walking machines are being considered. Accurate simulation models are being used in both cases to permit not only concept evaluation, but also the development of real-time control software through "hardware in the loop" simulation studies.

The MARIE project of Professor Rowe seeks to build an information-retrieval system for large multimedia databases that exploits the contents of the multimedia. This requires image processing, but especially natural-language processing since descriptive captions are often associated with valuable multimedia data and are much faster to analyze than images. MARIE exploits a large technical lexicon and a trainable statistical parser using statistics on word senses, syntactically-grouped word-sense pairs, parse rules, and rhetorical heuristics. MARIE's image processing uses robust natural-image segmentation methods, together with a neural network for classifying regions; the network also exploits linguistic reference information. MARIE also addresses system-building issues for large multimedia databases by considering the problem as one of efficient information filtering of desired data. Professor Rowe has developed mathematical criteria for optimal such information filtering, including data-parallel implementations.

The METUTOR project of Professor Rowe helps teachers write and run tutors for tasks involving sequences of actions. With METUTOR, tutors are considerably easier to build than with conventional frame-based tools, while at the same time being smarter in analyzing student behavior. METUTOR tutors use planning methods of artificial intelligence to figure out what a student is trying to do, which gives powerful inference capabilities for finding student errors, categorizing them, and tutoring them. METUTOR permits mapping of domain concepts to graphical elements, which are then combined into a visual display of domain state.

Professor Rowe also conducts research in construction of universal (all-situations) plans for robots moving in natural domains. These are like potential fields but better: They give the provably best thing to do in any situation.

Parallel, Distributed, and Network Computing

Designers of high performance computing systems are increasingly turning to parallel processor systems to achieve high speed at relatively low cost. In such a system, processing elements are duplicated (numbering in the hundreds or thousands) and often the memory is distributed to support parallelism. While the hardware has been rapidly improving, the software for such machines is still archaic. There is no agreement on how to program these machines, nor on the best way to design a parallel programming language, compiler, operating system, or application program. Thus, the central focus of Professor Lewis' research has been in the design and development of parallel programming environments which support architecture-independent parallel programming.

Recently, in a joint research project between NPS and the Russian Academy of Sciences Systems Programming Institute in Moscow, Russia, Professor Lewis is designing and implementing a parallel programming environment called mpC. This is a language, translator, and scheduling system for automatically mapping a parallel program written in mpC onto an arbitrary parallel computer. The network features of mpC permit rather general expression of the solution to a problem in terms convenient to the programmer. But this may be non-optimal use of the parallel hardware. Therefore, scheduling tools are needed to optimize the performance on a specific machine.

The hardware necessary to create a meta-computer has existed for twenty years. Likewise, heterogeneous programs-consisting of multiple parts, each running in a predefined sequence and on potentially different machines-have been around since the Sixties; these programs have been very latency-tolerant, meaning that the results from one part of a program often had to be written to tape and hand carried to another computer where the next part would execute. The demands of today's environments, particularly that of the military world, can no longer tolerate these latencies. In a crisis situation, where data acquisition, transfer, computation, and display must happen within minutes to be of any use, traditional methods have become outdated and, indeed, dangerous. At a basic level, a meta-computer is a distributed and heterogeneous collection of computers networked together, all coordinated by one or more master schedulers. Such a meta-computer can potentially, and in a matter of minutes, process a request from a hot spot, acquire the data from satellite, compute in a secure facility in the U.S., and present the results to the field commander somewhere in the Middle East. In addition, the meta-computer might be processing hundreds of such requests simultaneously.

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Professor Kidd's research generally involves the architectural design of such a meta-computer. To this end, he has created the Heterogeneous Processing Testbed (HPT) in the Heterogeneous Processing Laboratory (HPL). The HPL supports research in meta-computing and heterogeneous processing by providing a fully controlled environment for testing, development and evaluation.

In a distributed and heterogeneous environment, two of the biggest issues are where and when to schedule jobs. Though seemingly settled for "single box" architectures, it is far from solved in a distributed environment, especially one which combines many "boxes" of highly varying architectures. Some of the issues Professor Kidd's research attempts to address are: (1) what optimization criteria should we use, (2) how do you schedule jobs to meet various constraints on when and where they are to execute, such as job A must execute in parallel with job B and before job C, (3) how do you avoid resource contention related to the sharing of resources, such as disks, CPUs and networks, by different jobs, and (4) how do you meet the optimization criteria.

One ingrained assumption underlying Computer Science is determinism. Though never completely true, it has been "good enough" in traditional architectures. As the development of distributed computer evolves, determinism is no longer a valid assumption/simplification. Uncertainties derived from various sources, such as network traffic, shared disk use, and cache use, make job runtimes and other time related events better represented by a probability distribution. To this end, Professor Kidd and Professor Hengsen's research applies probabilistic and statistical techniques in scheduling and learning.

Professor Hengsen is one of the Principal Investigators for the Management System for Heterogeneous Networks (MSHN) Project, sponsored by DARPA under its Quorum Project. This research for MSHN is conducted by several faculty members here at NPS (Hengsen, Kidd, and Irvine), staff and students here at NPS, as well as researchers at NRaD, Purdue, and the University of Southern California. The goal of MSHN is to deliver good end-to-end quality of service to users in environments where both the heterogeneous resources and user set are dynamically changing. MSHN will serve a mixture of applications ranging from compute-intensive to I/O-intensive to interactive and real-time. Professor Hengsen's main area of research within the MSHN project is prioritized management of the multiple shared resources. In particular, it is extremely important to carefully model various classes of shared computing resources which differ greatly from other resources which we typically share.

In addition to the MSHN project, Professor Hengsen and some of her students participate in NRaD's SmartNet project, a scheduling advisor for heterogeneous computing resources. SmartNet has been used within DoD for compute-intensive jobs and the NPS team is currently investigating something similar for communication-intensive jobs.

With her students, Professor Hengsen has also built Graze, a graphical, performance debugger for parallel computing and Concurra, a software system that generates multi-threaded applications whose concurrency is provably correct and which are free from deadlock. One of her current students is investigating the use of Graze to monitor Java programs as well as its use in determining when certain compiler directives should be used with automatically parallelizing compilers. This will be useful to applications being written for FLEETNUMERIC and the Pacific Disaster Center.

Professor Lundy's research interests are in telecommunications networks and computer networks generally. Most of this work has been in the specification, analysis and testing of communications protocols. This often leads him to suggestions for possible improvements of existing protocols, correcting errors in them, or both. Recent work is in high speed transport protocols, multicasting protocols for reliable communications, and wireless protocols. Professor Lundy is also interested in military communications and in network security. In the past year, Professor Lundy has been studying and evaluating some of the U.S. Army's current networks and their future plans for these networks.

Network guarantees of quality of services required for the transport of multimedia data such as digital audio and video. Specifically, end-to-end transfer delays and loss rate of a multimedia data flow must be bounded below specified values. The objective of Professor Xie's research is to design networks that provide these guarantees. During the past two years, Professor Xie has developed a new network architecture (called Burst Scheduling network), and a set of algorithms for providing end-to-end delay guarantees. The algorithms are highly efficient, suitable for high speed implementation.

Professor Xie's current focus is on the development of an application-level guaranteed statistical service. The service is characterized by: (1) a bound on loss rate of application-level data units (e.g., pictures in a video application), (2) data losses distributed fairly among flows subscribing to the service and uniformly over the duration of each flow, and (3) a deterministic traffic model that promotes statistical multiplexing in the network. More specifically, a flow is modeled as a sequence of bursts, each of which carries the bits of an application-level data unit (ADU). The first and

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last packet of each burst are marked, and the first packet carries information on the ADU (including the bandwidth requirement). The traffic model enables admission control at the burst level as well as the flow level. To achieve high network utilization, overbooking is allowed in flow level admission control. Burst level admission control, on the other hand, is used to ensure that the capacity of each network channel is not exceeded by bandwidths allocated to flows such that delay guarantees can be provided. The guaranteed statistical service will greatly enhance the ability of existing networks to support distributed multimedia applications such as remote teaching and video on demand.

Computer Security

As the value of the assets stored in computer systems increases, attacks by highly motivated, technically capable opponents using malicious software and subversive techniques become more likely. A scientific foundation exists which may be employed to build secure computer systems and certified software to protect sensitive information. Several areas of research are being pursued.

The widespread use of commercial off-the-shelf (COTS) platforms enforcing security policies with a high level of assurance has been hampered by a lack of compatibility with existing COTS and government-off-the-shelf applications software. Trusted file system research is intended to permit the use of both high assurance security policy-enforcing platforms and the massive body of application software currently available. Professor Irvine's government-industry team plans to build a prototype system providing high assurance controlled sharing of information while allowing users to continue to run their favorite COTS workstation applications. An extension to the initial effort would be the development of a high assurance messaging capability permitting the selection of cryptographic keys and methods based on information security levels.

Without careful analysis, execution of application software can sometimes result in the corruption or exfiltration of sensitive information. Professors Irvine and Volpano are developing a type system in which it is possible to prove that code is secure. The objective of this research is to construct a tool to detect places where either legacy or new software is leaking information. Standard type inference techniques will be used in the implementation so that, within a typical software development tool such as an editor, users will be informed automatically regarding the security properties of their programs. This could be useful in the context of Web programming where perhaps a downloaded script attempts to make some sensitive information about the user, say a mail folder, publicly available by mailing it to everyone. Such unauthorized disclosures would be prevented if the script were type checked in a system prior to execution.

The use of covert techniques to export sensitive information from trusted systems is also being explored by Professor Irvine. This research will include the analysis of encoding techniques for exploitive purposes as well as empirical studies of the efficacy of these covert techniques.

Databases

Professor Wu's main research interest is in creating a unified database front-end system that provides easy-to-use yet powerful common language to access varying types of relational data management system (RDBMS), and shields the complexity of underlying RDBMS. His system called GLAD II (Graphics Language for Accessing Database) allows users to interact with different relational DBMS by providing a common graphic language called DFQL (Data Flow Query Language) that is based on a data flow diagram. The system automatically translates a user specified DFQL query into the equivalent query statements recognized by the connected backend DBMS. At present, the prototype connects to Oracle and translates the DFQL queries into the Oracle's SQL statements.

Professor Wu's work is different from other similar-looking work and commercial products in that theirs only support a SQL connectivity, i.e. theirs do not shield users from the complexity of SQL. In contrast, DFQL provides a more logical, higher-level, and consistent query language. Users of DFQL do not have to bother with the poorly designed language features in SQL. In other words, theirs do not eliminate the semantics problem associated with data retrieval. DFQL is a graphic query language based on relational algebra. It has been designed with sufficient expressive power and functionality to allow the user to easily express database queries. DFQL is relationally complete and includes an implementation of aggregate functions. An object-oriented implementation allows programmers to easily create their own DFQL operators from the primitive and other existing user-defined operations. This extensibility of

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query language is unique, no other query language allows such extensibility. The overall intention is to provide the user with a simple-to-use, yet powerful and extensible tool to implement database queries. A human-factors analysis comparing DFQL and SQL showed DFQL was statistically better than SQL.

PROJECT SUMMARIES

REALISTIC BATTLEFIELD SIMULATION

Wolfgang Baer, Research Associate

Department of Computer Science

Sponsors: U.S. Army Test and Experimentation Command (TEXCOM) and
U.S. Army Training and Doctrine Analysis Command (TRADOC)

OBJECTIVE: Development of highly realistic tactical battlefield simulation systems for weapons test, training, mission rehearsal, and analysis applications on low cost networked PC platforms.

SUMMARY: Research for the development of highly realistic tactical battlefield simulation systems is organized around three main areas. These are: (1) Development of algorithms for visualizing realistic battlefield effects including 1 meter or better terrain backgrounds, photo realistic targets, and environmental effects and battlefield obscurants, (2) Development of Database generation and update systems designed to reduce instrumentation, photographic, and video data to object descriptor data bases, and (3) Development of high speed low cost parallel processor technologies in order to execute the algorithms and systems resulting from the two previous areas.

During FY96 specific research activities included the development of benchmark tests of networked Pentium based machines under the Linux operating system to determine the feasibility of using low cost commercial components to host high speed simulations. Both MPI/ LAM and native Unix Socket codes were developed and compared. Test results indicate that the Pentium PC is a viable substitute for simulation workstation applications, however, network communications overhead prevents cost effective implementation of parallel visualization engines. As the result of this research a Dual Pentium Pro machine was specified and procured in order to test the relative efficiency of a Symmetric Multi-Processor (SMP) machine as a networked node.

The initialization and data creation toolbox developed in '95 which allowed standard data sources (DTED and SPOT) to be integrated with high resolution aerial photographs was expanded to allow input of commercial high resolution digital elevation data. The tool was then used for creation and delivery of high resolution databases for Ft. Hood, TX and Camp Shelby, MS. The databases were used in after-action review systems during training exercises during the Fall of 1996 with "awesome" results.

Under contract from the Defense Mapping Agency (DMA) a study was conducted on the assessment and design of "Value Added Methodologies for High Resolution Terrain Data Generation." This work provided both software prototype and techniques for extending operations at the DMA in order to improve current map products and provide computer-oriented products required by the modeling and simulation community in the future.

In parallel to the above efforts theoretical investigations into the computer modeling of theoretical physics and reality representation (Church-Turing Principle) has been followed with the advice and guidance of R. Hamming. Several papers including, "Hidden Variables and The Physical Interpretation of the Wave Function in Quantum Theory," have been written but have not yet been accepted for publication.

CONFERENCE PRESENTATIONS:

Baer, W., "High Resolution Terrain Representations for Live-Virtual Test Applications," presented at the 64th MORS Symposium, TRADOC Analysis Center, Ft. Leavenworth, KS, 18-20 June 1996.

Baer, W., "Live Virtual Simulation for Operational Testing: System Design at Ft. Hunter Liggett," presented at the 64th MORS Symposium TRADOC Analysis Center, Ft. Leavenworth, KS, 18-20 June 1996.

OTHER:

Baer, W., Reed, C., "Value Added Methodologies for High Resolution Terrain," July 1996, and "Value Added Methodologies for High Resolution Terrain" September 1996. Prepared for: Dr. Young, Sull/TMPO, Defense Mapping Agency Acquisition and Technology Group, Attn.: ATCT, MS A-13, 8615 Lee Highway, Fairfax, VA 22031.

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Baer, W., Decato, S.W., Akyuz, E., "Suitability and Performance Assessment of Commercial Off-the-Shelf PC Equipment for Parallel High Resolution Battlefield Simulation." Prepared for: Texcom Experimentation Center, Fort Hunter Liggett, Jolon, CA, 93928, 1996.

Baer, W., PC LINUX version of, "Latitude Longitude Based Global Perspective View Generator," developed for TEXCOM Fort Hunter Liggett, CA, and TRAC, Monterey, CA, 1996.

Baer, W., Reed, C., High resolution expansion and Janus Terrain conversion add-on to, "Terrain Database Initialization and Conversion Toolbox," SUN based C Software Program developed for TEXCOM, Fort Hunter Liggett, CA, and MISC, Huntsville, AL, 1996.

DoD KEY TECHNOLOGY AREAS: Other (Networked PC Clusters for Realistic Battlefield Simulation)

KEYWORDS: Modeling, battlefield visualization, distributed processing

AUTOMATED REASONING FOR COMBINING CHANGES TO SOFTWARE SYSTEMS

Valdis Berzins, Professor

Department of Computer Science

Sponsor: U.S. Army Artificial Intelligence Center

OBJECTIVE: The objective of the proposed research is to provide computer aid for software evolution, particularly in the critical early stages of determining requirements and software architectures. To make significant improvements in the productivity and accuracy of the software development process, tools are needed that go beyond design editing facilities to provide decision support to the designers and to completely automate some of the easier design decisions. Automated reasoning is needed to accomplish this. The focus is on decision support for combining changes to software systems because it is a practically important special case of software evolution and synthesis that is more tractable than the unrestricted general problem.

SUMMARY: This project investigated effective automated reasoning support for combining changes to software systems. This capability is relevant for reliably combining the results of concurrently developed enhancements to a software system. Improved decision support in this area should reduce the incidence of software system integration problems. Expected benefits include automated assistance for combining different changes to a proposed design, assessing their consistency and reconciling conflicts between changes. Reliable and accurate tools for change-merging will facilitate distributing design tasks on a large software development project to a group of engineers working concurrently, as well as propagating changes to software families that support many configurations for the same system. The first methods for automatically combining changes to software design structures, and for automatically detecting and correcting conflicts between concurrent changes have been developed. Also developed are methods for combining deep changes to software specifications - changes that modify module interface and module signatures as well as module behavior.

PUBLICATIONS:

Berzins, V., Dampier, D., "Software Merge: Combining Changes to Decompositions," Journal of Systems Integration, special issue on Computer-Aided Prototyping, Vol. 6, No. 1-2, pp. 135-150, 1996.

Berzins, V., "Recombining Changes to Software Specifications," Proceedings of the 8th International Conference on Software Engineering and Knowledge Engineering, Lake Tahoe, CA, pp. 136-144, June 1996.

CONFERENCE PRESENTATIONS:

Berzins, V., "Software Change Merging for Prototype Evolution," ARO, Research Triangle Park, NC, 6-8 February 1996.

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Berzins, V., "Software Change Merging for Prototype Evolution," C.V. Ramamoorthy Workshop on Advances in Computer Science and Engineering, University of California at Berkeley, CA, 4 May 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Artificial intelligence, software engineering, change merging, automation

COMPUTER-AIDED PROTOTYPING APPLIED TO ARMY TACTICAL MISSILE COMMAND SYSTEM (ATACMS)

Valdis Berzins, Professor

Luqi, Professor

Department of Computer Science

Sponsor: U.S. Army Research Laboratory

OBJECTIVE: The Computer-Aided Prototyping System (CAPS) is an integrated software development environment aimed at rapidly prototyping hard real-time embedded software systems, such as missile guidance systems, space shuttle avionics systems, robots, automated factories, telecommunications systems, computer-controlled vehicles, and computer-controlled consumer appliances such as microwave ovens and sewing machines. The objective of this project is to use the Computer-Aided Prototyping System developed at the Naval Postgraduate School to evaluate and refine the requirements for the Army Tactical Missile System. This will improve the quality of the product and its interoperability across different branches of DoD.

SUMMARY: This project focuses on the analysis, modeling, and prototyping of the requirements of the Army Tactical Missile System. The draft MOA of the ATACMS was analyzed and CAPS was used to develop a software prototype to capture the dynamic aspects of the requirements. The requirements are then refined through an iterative prototyping process characterized by exploratory design and extensive prototype evolution. The prototype focuses on the key areas of uncertainty in the requirements, which were determined to be the connections between the sensors and the fire control centers.

OTHER:

Berzins, V., Luqi, Progress report on "Computer-Aided Prototyping Applied to ATACMS," Computer Science Department, Naval Postgraduate School, December 1996.

THESIS DIRECTED:

Angrisani D., and Whitbeck, G., "Software System Requirements for the Army Tactical Missile System," Master's Thesis, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Embedded system, software requirements, computer-aided software development

HIGH-FIDELITY MODEL DEVELOPMENT FOR VIRTUAL ENVIRONMENT NAVIGATION TRAINING

Rudolph P. Darken, Assistant Professor

Department of Computer Science

Sponsor: Naval Research Laboratory

OBJECTIVE: The overall goal of this research is to investigate how people navigate and acquire spatial knowledge of virtual environments and how that knowledge transfers to real world navigation tasks. A necessary precursor to this

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work involves the creation of suitable virtual models to be used in the training phase of the experimentation. These models must be both visually and spatially correct.

SUMMARY: The first step in this research involves a straightforward training transfer study of navigation performance from virtual to real environments. The environment to be used for this study is a large warehouse on the campus of the Massachusetts Institute of Technology. For this step, the model needed must be of the highest fidelity possible. This requires that photo textures be taken of the entire physical space. The model has been constructed based on blueprint measurements of the actual building. At this point, the geometry of the model has been completely constructed but the textures have not yet been applied to the geometry. There remain issues involving texture scale and visual features that have not yet been resolved. The results of this work will be used in an FY97 project for the Office of Naval Research that will involve the actual experimentation for this study.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training, Human Systems Interface, Modeling and Simulation

KEYWORDS: Virtual environments, training, navigation

ACCESS RIGHTS TRANSITIVITY UNDER POLICY MODIFICATION

Cynthia Irvine, Assistant Professor
Dennis M. Volpano, Assistant Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: The primary objective of this project is to develop algorithms capable of statically analyzing code, targeted for remote execution, for secure flow violations. The algorithm will attempt to construct a proof, for a given program, in a sound flow logic, thereby establishing the program is secure. The algorithm will permit remote code, written in Web-based languages like Java and JavaScript, to be analyzed prior to execution in order to determine whether it can be executed safely.

SUMMARY: The project aims to incrementally develop a secure flow logic for a deterministic, imperative programming language. The PIs are starting with a logic that characterizes the early work in secure flow static analysis by Dorothy Denning. The idea is to treat secure-flow analysis as a form of type checking in the context of subtypes. Types correspond to security levels and upward flows between levels are modeled naturally by subtyping. There is a notion of procedural polymorphism that arises when the body of a procedure does not fix the security level of a formal parameter. A type checker in this setting corresponds to a flow checker. Viewing flow analysis in this way affords an opportunity to apply powerful and well-understood type inference techniques. Flow hypotheses that the flow checker finds are necessary to prove a program secure in the logic are inferred automatically. They manifest themselves as subtype constraints in a principal type scheme inferred for the program. This has an advantage over Denning-style flow checking, and other more recent proposals, in that this form of flow analysis can be applied to legacy code without requiring the code to be annotated or modified any way.

PUBLICATION:

Volpano, D., "Provably-Secure Programming Languages for Remote Evaluation," ACM Electronic Computing Surveys, Vol. 28A, December 1996.

CONFERENCE PRESENTATION:

Irvine, C., "Type Systems for Secure Remote Evaluation," 12th Mathematical Foundations of Programming Semantics, Boulder, CO, June 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software

PROJECT SUMMARIES

KEYWORDS: Computer security, interoperation, secure information flow, Web languages

INFORMATION FLOW IN COMPUTER SYSTEMS

Cynthia Irvine, Assistant Professor

Department of Computer Science

Sponsor: Naval Postgraduate School

OBJECTIVE: The objective of this research was to address selected fundamental problems in identifying sources of illicit information flow in computer systems.

SUMMARY: In a continuation of work on applications for multilevel systems, a design for a high assurance trusted file service using commercial-off-the-shelf (COTS) products to create a local area network (LAN) was refined. Unlike security in a monolithic system, a high assurance LAN must provide a means for individual users to authenticate themselves to the reference monitor so that process IDs can be associated with the security level of the user. This places a joint burden on the workstation and the file server to provide a trusted path. Current efforts have focused on the feasibility of integrating current designs for trusted network interface cards (NICs) with trusted servers and the challenge of providing security over the LAN itself.

The project permitted the start of an investigation into the effects of compression algorithms on the effectiveness of steganography to encode information in imagery. In a series of experiments using several coding techniques, it was discovered that approximately 70% of the information steganographically hidden in the imagery subjected to JPEG compression was lost. To support this effort a toolkit was built to provide a graphical user interface for image selection, encoding with any of a variety of steganographic encoding algorithms, and compression/decompression.

THESIS DIRECTED:

Wootten, D., "A Graphic User Interface for Rapid Integration of Steganography Software," Master's Thesis, Naval Postgraduate School, March 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Computer security, INFOSEC, multilevel security, distributed systems security, applications security

AUTOMATED SANITATION OF CLASSIFIED IMAGERY

Cynthia Irvine, Assistant Professor

Timothy Shimeall, Associate Professor

Dennis M. Volpano, Assistant Professor

Department of Computer Science

Sponsor: Defense Information Agency

OBJECTIVE: The objective of this research is to address issues associated with the articulation of sanitization policies for information filtering systems. Policy categorization and decomposition need to be addressed for both release policies and meta non-release policies. This will be followed by an examination of the interaction between policies and potential models for representing policies. Methods will be examined to automate policy comparison with the objective of checking a new precedence over all release policies

SUMMARY: This Central Imagery extensive analysis of imagery data formats, current declassification rules and discussions with Creative Imaging Office (CIO) personnel to identify and categorize issues involved in the automatic declassification of images and their associated annotation data. The policies involved in the declassification of imagery and the formats used in imagery data were found to permit a matching of the problem of automatic image declassification with the problem of token recognition and categorization. Token recognition and categorization is known to be expressible by regular expressions. Regular expressions are an abstract class of notations that can permit the proof of a

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number of desirable properties including completeness, consistency, subsetting and compliance with regulations. This research, however, ceased with the matching of the imagery declassification problem with the token recognition problem; further effort is needed to establish the proof system.

THESIS DIRECTED:

Fulp, J.D., "A National Imagery System Security Policy," Master's Thesis, Naval Postgraduate School, March 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Computer security, INFOSEC, public key cryptography, distributed trusted systems

SUPPORT FOR NPS INFORMATION SYSTEMS SECURITY (INFOSEC) RESEARCH PROGRAM, PHASE II

**Cynthia Irvine, Assistant Professor
Department of Computer Science
Sponsor: National Security Agency**

OBJECTIVE: The objective of this research is to support the development of a center for research and education in information systems security at NPS. The effort is intended to provide military officers basic and advanced education in the area of computer and information systems security. The program is intended to be a continuing source of high-quality information systems security research focusing on problems of critical importance to the military services. A goal will be to obtain military officers with advanced degrees in technical disciplines for identified billets within the National Security Agency.

SUMMARY: This research supports an ongoing effort to develop the computer security and INFOSEC research and education program of the Computer Science Department at the Naval Postgraduate School. As a result of this effort the Naval Postgraduate School Center for Information Systems Security and Research (NPS CISR) was formally established in October 1996. NPS CISR includes Computer Science Department faculty, staff and students participating in courses and research.

In the area of course development, NPS CISR will host a small two-day workshop to assist in the establishment of a non-DoD CISR at a civilian university. During the fall quarter of FY97 NPS CISR hosted its first Visiting Professor, William R. Shockley, who developed and taught a course of Security Policy and Models. NPS faculty restructured Introduction to Computer Security and, with the assistance of staff supported under this contract, added extensive laboratory exercises. This research provided partial support for the development of two courses: Network Security Management of Secure Systems, both of which will be offered in FY97. The program allowed some modest enhancements to the INFOSEC and Trusted Systems Laboratory, however, much more is required in this area. Finally, the program supported faculty and student research. This included an examination of the effects of the use of the JPEG compression algorithm on steganographically modified imagery. In addition, the program supported ongoing research in the area of multilevel security and security in operating systems.

PUBLICATION:

Currie, D. L., and Irvine, Cynthia E., "Surmounting the Effects of Lossy Compression in Steganography," Proceeding of the 19th Information Systems Security Conference, Baltimore, MD, pp. 194-201, October 1996.

CONFERENCE PRESENTATIONS:

Irvine, C. E., "Operating System Security," Panel discussion, DARPA 2nd Workshop on Operating System Security, Alexandria, VA, November 1996.

PROJECT SUMMARIES

Currie, D. L. and Irvine, C. E., "Surmounting the Effects of Lossy Compression in Steganography," 19th Information Systems Security Conference, October 1996.

THESES DIRECTED:

Heaton, L. A., "Radiant Mercury: An Assessment of the Issues," Master's Thesis, Naval Postgraduate School, September 1996.

Lucas, J., "Ensuring a C2 Level of Trust and Interoperability in a Networked Windows NT Environment," Master's Thesis, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Computer security, INFOSEC, cryptography, distributed trusted systems

INFORMATION SYSTEMS SECURITY (INFOSEC) RESEARCH AND EDUCATION PROGRAM

Cynthia Irvine, Assistant Professor

Department of Computer Science

Sponsor: National Security Agency

OBJECTIVE: The objective of this research is to continue an effort to develop a program in computer security research at NPS, provide computer security and INFOSEC education as part of the academic program for military officers and support a computer specialization for military officers.

SUMMARY: In support of computer security research, the project permitted the initiation of an effort to incrementally develop a secure flow logic for a deterministic, imperative programming language. The PIs are starting with a logic that characterizes the early work in secure flow static analysis by Dorothy Denning. The idea is to treat secure-flow analysis as a form of type checking in the context of subtypes. Types correspond to security levels and upward flows between levels are modeled naturally by subtyping. There is a notion of procedural polymorphism that arises when the body of a procedure does not fix the security level of a formal parameter. A type checker in this setting corresponds to a flow checker. Viewing flow analysis in this way affords an opportunity to apply powerful and well-understood type inference techniques. Flow hypotheses that the flow checker finds are necessary to prove a program secure in the logic are inferred automatically. They manifest themselves as subtype constraints in a principal type scheme inferred for the program. This has an advantage over Denning-style flow checking, and other more recent proposals, in that this form of flow analysis can be applied to legacy code without requiring the code to be annotated or modified in any way.

The project permitted the start of an investigation into the effects of compression algorithms on the effectiveness of steganography to encode information in imagery. In a series of experiments using several coding techniques, it was discovered that approximately 70% of the information steganographically hidden in the imagery subjected to JPEG compression was lost. To support this effort a toolkit was built to provide a graphical user interface for image selection, encoding with any of a variety of steganographic encoding algorithms, and compression/decompression.

A high-level design for a multilevel file service based on the use of commercial-off-the-shelf (COTS) products was developed. Its intent is to permit the use of commercial software operating systems and applications on workstations while providing high assurance that access to information at different security classifications was permitted only to authorized users. This would be achieved by placing access decisions within a TCSEC Class B3 or A1 reference monitor.

PUBLICATION:

Volpano, D. and Smith, G., "On the Systematic Design of Web Languages," ACM Computing Surveys, Vol. 28, No. 2, pp. 315-317, June 1996.

PROJECT SUMMARIES

THESES DIRECTED:

Campbell, H., and Currie, D. L., III, "Implementation and Efficiency of Steganographic Techniques in Bitmapped Images and Embedded Data Survivability Against Lossy Compression Schemes," Master's Thesis, Naval Postgraduate School, March 1996.

Marlett, R., "Analysis of General Magic Telescript with Respect to Class C2 Requirements," Master's Thesis, Naval Postgraduate School, September 1996.

CONFERENCE PRESENTATION:

Volpano, D., "Type Systems for Secure Remote Evaluation," 12th Mathematical Foundations of Programming Semantics, Boulder, CO, June 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Computer security, multilevel security, secure information flow, encryption

INFORMATION SYSTEMS SECURITY (INFOSEC)

Cynthia Irvine, Assistant Professor
Department of Computer Science
Sponsor: National Security Agency

OBJECTIVE: The objective of this research is to support the development of a center for research and education in information systems security at NPS. The effort is intended to provide military officers basic and advanced education in the area of computer and information systems security. The program is intended to be a continuing source of high-quality information systems security research focusing on problems of critical importance to the military services. A goal will be to obtain military officers with advanced degrees in technical disciplines for identified billets within the National Security Agency.

SUMMARY: This research was the first phase of a multi-year effort to expand the computer security and INFOSEC research and education program of the Computer Science Department at the Naval Postgraduate School. In the area of course development, NPS CISR will host a small two-day workshop to assist in the establishment of a non-DoD CISR at a civilian university. During the fall quarter of FY97 NPS CISR hosted its first Visiting Professor, William R. Shockley, who developed and taught a course of Security Policy and Models. NPS faculty restructured Introduction to Computer Security and, with the assistance of staff supported under this contract, added extensive laboratory exercises. This research provided partial support for the development of two courses: Network Security Management of Secure Systems, both of which will be offered in FY97. The program allowed some modest enhancements to the INFOSEC and Trusted Systems Laboratory, however, much more is required in this area. Finally, the program supported faculty and student research. This included an examination of the effects of the use of the JPEG compression algorithm on steganographically modified imagery. In addition, the program supported ongoing research in the area of multilevel security and security in operating systems. In a series of experiments using several coding techniques, it was discovered that approximately 70% of the information steganographically hidden in the imagery subjected to JPEG compression was lost. To support this effort a toolkit was built to provide a graphical user interface for image selection, encoding with any of a variety of steganographic encoding algorithms, and compression/decompression.

PUBLICATION:

Irvine, C. E., "Goals for Computer Security Education," Proceedings of the IEEE Symposium on Security and Privacy, Oakland, CA, May 1996, pp 24-25.

PROJECT SUMMARIES

CONFERENCE PRESENTATIONS:

Irvine, C. E., "Goals for Computer Security Education," IEEE Symposium on Security and Privacy, Oakland, CA, May 1996.

Irvine, C. E., "Graduate Education in Computer Security," INFOSEC Research Council, Alexandria, VA, August 1996.

THESIS DIRECTED:

Campbell, H. and Currie, III, D. L., "Implementation and Efficiency of Steganographic Techniques in Bitmapped Images and Embedded Data Survivability Against Lossy Compression Schemes," Master's Thesis, Naval Postgraduate School, March 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: INFOSEC, computer security, cryptography, education

NAVAL POSTGRADUATE SCHOOL CENTER FOR INFORMATION SYSTEMS SECURITY AND RESEARCH (NPS CISR) STUDENT RESEARCH TOPICS

Cynthia Irvine, Assistant Professor

Department of Computer Science

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The primary objective of this project is to support student research topics of particular relevance and interest to SPAWAR. Current thesis work includes: (1) a study of the use of public key cryptography to protect sensitive but unclassified (SBU) information, including information covered by the Privacy Act, when transmitted between Department of Navy installations across the Internet, (2) an investigation of currently available products as components in shipboard MLS LANs, and (3) security analysis of the use of Java for application software in JMCIS-Ashore.

SUMMARY: As a result of this support, several students conducting thesis research on INFOSEC topics of interest to SPAWAR have been able to attend workshops, conferences, and meetings to further their research objectives. In particular, students working in the area of multilevel security for Department of Navy communications systems attended the National Information Systems Security Conference in Baltimore, MD in October 1996. There they were able to meet with other researchers pursuing the development of high assurance trusted systems for the purpose of exchanging project information. In December 1996, students were able to visit NRaD to discuss research on the use of code developed for remote execution. NRaD is developing a prototype system to use Java applets for applications such as message processing. The NPS students are studying the security ramifications of that design.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Computer security, INFOSEC, MLS, public key cryptography, distributed trusted systems

COMPUTER SIMULATION AND CONTROL OF AUTONOMOUS UNDERWATER WALKING ROBOTS

Yutaka Kanayama, Professor

Robert B. McGhee, Professor

Department of Computer Science

Sponsor: National Science Foundation

OBJECTIVES: The overall objectives of this project are to investigate problems related to gait planning, motion control, and their simulation on autonomous underwater walking robots. This is an international joint project operated

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by the Naval Postgraduate School and by the Port and Harbor Research Institute (PHRI) in Japan. The year of 1996 was the last of the three-year period.

SUMMARY: This research project was concluded and the accomplishments were evaluated as extremely successful. The main research activities were done in the six areas: (1) versatile gait planning algorithm, (2) embodying smooth body motions, (3) smooth foot motion planning, (4) 3D computer simulation of walking robots, (5) $O(n)$ method for dynamic simulation of walking robots, and (6) rational behavior model for intelligent robot's behavior.

PUBLICATION:

Yoneda, K., Suzuki, K., Kanayama, Y., Takahashi, H., and Akizono, J., "Gait and Foot Trajectory Planning for Versatile Motions of a Six Legged Robot," Technical Report, NPS-CS-010, Naval Postgraduate School, October 1996.

CONFERENCE PRESENTATION:

Akizono, J., Takahashi, H., Kanayama, Y., Yoneda, K., Suzuki, K., Tanaka, T., and McGhee, R., "The Results of an International Joint Research Project on an Underwater Walking Robot," Proceedings of International Symposium on Techno-Ocean, Kobe, Japan, pp. 467-472, 23-25 October 1996.

THESES DIRECTED:

Remias, L.V., "A Real-Time Image Understanding System for An Autonomous Mobile Robot," Master's Thesis, Naval Postgraduate School, March 1996.

Papadatos, A., "Research on Motion Planning of Autonomous Mobile Robot," Master's Thesis, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Robotics, underwater robots, walking robots, autonomous robots, gait planning, rational behavior model

AUTONOMOUS ROTARY VEHICLE

Yutaka Kanayama, Professor

Department of Computer Science

Sponsor: Naval Postgraduate School

OBJECTIVE: This project is related to a "rotary vehicle," which has four wheels, each of which is steerable and drivable. With this novel kinematic architecture, this vehicle is expected to have two striking features kinematic motion freedom and stronger traction. We would like use this vehicle for UXO/Mine clearing tasks.

SUMMARY: The design and construction of the hardware system was finished in September 1996. The real-time software system design was finished by the end of the fiscal year and then the real developmental tasks started.

PUBLICATIONS:

Kanayama, Y. and Fahroo, F., "A New Line Tracking Method for Nonholonomic Vehicles," Submitted to the IEEE Transactions on Robotics and Automation, September 1996.

Yoneda, K., Suzuki, K., Kanayama, Y., Takahashi, H., and Akizono, J., "Gait and Foot Trajectory Planning for Versatile Motions of a Six-Legged Robot," Technical Report, NPS-CS-010, Naval Postgraduate School, October 1996.

PROJECT SUMMARIES

CONFERENCE PRESENTATION:

George, R., and Kanayama, Y., "A Rate-Monotonic Scheduler for the Real-Time Control of Autonomous Robots," Proceedings of IEEE International Conference on Robotics and Automation, in Minneapolis, MN, pp. 2804-2809, 22-28 April 1996.

THESIS DIRECTED:

Wahdan, M., "New Motion Planning and Real Time Localization Methods Using Proximity for an Autonomous Mobile Robot," Ph.D. Dissertation, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Ground Vehicles

KEYWORDS: Robotics, autonomous ground vehicles, rotational motion freedom, stronger traction, UXO detection, UXO clearing, demining

TECHNIQUES IN NATURAL COMPUTING

Ted Lewis, Professor

Som Karamchetty, Visiting Professor

Department of Computer Science

Sponsor: U.S. Army Research Laboratory

OBJECTIVE: To develop techniques for non-programmers to develop computational procedures.

SUMMARY: Natural computing means the application of non-programming language techniques to the development of computational procedures in engineering. This includes visual and indirect mechanisms for defining functions used to compute equations in engineering.

DoD KEY TECHNOLOGY AREAS: Other (Modeling and analysis of engineering problems)

KEYWORDS: Visual computing, non-procedural programming

JOINT USA-RUSSIA RESEARCH IN PORTABLE PARALLEL PROGRAMMING LANGUAGE

Ted Lewis, Professor

Department of Computer Science

Sponsor: Office of Naval Research

OBJECTIVE: To design and implement a portable and efficient general purpose programming language for programming parallel computers.

SUMMARY: An extension to C, mpC, has been designed and implemented. This language produces efficient parallel programs for any system that supports the MPI standard. The language was cooperatively designed by United States and Russian scientists, and implemented by the Russians. It is freely available via the Internet.

PUBLICATIONS:

Lastovetsky, A., "mpC - a Multi-Paradigm Programming Language for Massively Parallel Computers," ACM SIGPLAN Notices, 31(2), pp. 13-20, February 1996.

PROJECT SUMMARIES

Arapov, D., Kalinov, A., and Lastovetsky, A., "Managing the Computing Space in the mpC Compiler," Proceedings of the 1996 Parallel Architectures and Compilation Techniques (PACT'96) Conference, Boston, MA, pp. 150-155, October 1996.

Arapov, D., Kalinov, A., Lastovetsky, and Lewis, T., "A Programming Environment for Heterogeneous Distributed Memory Machines," Proceedings of the 7th Heterogeneous Computing Workshop (HCW'97) of the International Parallel Processing Symposium (IPPS'97), IEEE Computer Society Press, Geneva, Switzerland.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Parallel computing, distributed computing

A COMPUTER AIDED PROTOTYPING SYSTEM FOR REAL-TIME ADA 95 SOFTWARE

Luqi, Professor

Department of Computer Science

Sponsor: ADA Joint Program Office

OBJECTIVE: The research for this project is aimed at developing a new version of the Computer-Aided Prototyping System (CAPS) tools to support the design and development of Ada 95 real-time embedded software. CAPS is an integrated set of software tools that generate real-time Ada programs directly from requirements. The CAPS system uses the fifth-generation language PSDL to model the communication structure and the timing and control constraints that comprise the requirements for an embedded software system. This notation is used to support automatic consistency checking, design completion, and automatic generation of Ada code as well as to document requirements and prototype designs. The code generated by CAPS is used to determine and demonstrate the implications of proposed software requirements.

SUMMARY: As part of the on-going effort to evaluate and improve CAPS, CAPS Release 1 was demonstrated to the attendees of the STC'96 in support of the U.S. Navy Booth. Many of those who saw the CAPS demonstrations were delighted to learn that CAPS Release 1 is in the public domain and they plan to install the software on their own machines. Feedback from users at NRaD, ARL and FLENUMMETOCEN was also solicited. While almost all users appreciate the automatic code generation capabilities of CAPS, they are frustrated in the lack of documentation and the steep learning curve in mastering the CAPS syntax-directed editor. Hence, a new CAPS Tutorial and user guides was developed to help the CAPS users. These documents will be included in the upcoming release of CAPS. The documents were also converted into HTML format to make them available via the Internet. Furthermore, a generic C3I workstation prototype was created using CAPS Release 1. The prototype consists of 12,000 lines of Ada source code. In addition, the design and development of the new components needed to support the generation of control codes for the Ada 95 real-time prototypes has been completed. In addition, a PSDL specification generator that automatically generates PSDL specifications from the specifications of existing Ada 95 packages was also developed.

OTHER: Software, CAPS Tutorial, CAPS Installation Manual

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Real-time embedded systems, computer-aided rapid prototyping, Ada95

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COMPUTER AIDED SUPPORT FOR THE PROTOTYPING OF ADA 95 REAL-TIME EMBEDDED SOFTWARE

Luqi, Professor
M.T. Shing, Associate Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: The proposed research is aimed at developing a new version of the Computer-Aided Prototyping System (CAPS) tools to support the design and development of Ada 95 real-time embedded software. It builds upon the success of the existing version of CAPS by converting it to generate Ada 95 code and extending it to take advantage of the new features of Ada 95 to generate better Ada application software. The new CAPS will ease the task of software migration from Ada 83 to Ada 95 and increase the use of Ada and software engineering principles by providing design automation capabilities and serving as an effective teaching tool for Ada real-time software development.

SUMMARY: In FY96, the PSDL translator, scheduler, PSDL predefined types in the CAPS execution support system were converted to generate Ada 95 code, and to extend these tools to take advantage of the new features of the Ada 95 to generate better Ada application software.

The translator generates Ada code that binds together the reusable components extracted from the software base. Its main functions are to implement data streams, control constraints, and timers. A new set of attribute equations for the translator specification based on the Ada 95 grammar was developed in order to create a new translator that generates Ada 95 code and to take advantage of the improved features of Ada 95. The scheduler first separates the time-critical operators from the non-time-critical ones and analyzes the schedulability of the time-critical operators. It then generates two Ada tasks to implement the static and dynamic schedules. The two code generation procedures were replaced by new ones in order to generate Ada 95 code.

The code generated by the translator and the scheduler makes use of several PSDL pre-defined abstract data types: "psdl exceptions," "psdl streams," "psdl timers," and "caps hardware model." The Ada packages implementing these abstract data types were converted to match the Ada 95 code. Ada 95 protected types were also used for mutual exclusion to improve the efficiency of these packages.

To make the prototyping process more efficient and user-friendly, we have extended the PSDL editor to incrementally analyze the semantic information of the prototype and perform feasibility checks during the editing phase. Users now can detect and receive warnings as they entered the design. The new editor has been applied to several prototypes examples. The results show that, by catching errors during the editing phase, the users save time and produce better quality products.

In addition, a new User Interface for the retrieval and integration of Ada 95 reusable components was developed.

THESES DIRECTED:

Grosenheider, S.R., "Enhancements for the CAPS Prototyping System Description Language Syntax-Directed Editor," Master's Thesis, Naval Postgraduate School, March 1996.

Hong, R. W., "User Interface and Database Design for Software Database of the Computer Aided Prototyping System (CAPS)," Master's Thesis, Naval Postgraduate School, March 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Ada 95, real-time embedded software, computer aided rapid prototyping

PROJECT SUMMARIES

FORMAL MODELS USED FOR AUTOMATION IN SOFTWARE DEVELOPMENT

Luqi, Professor
Valdis Berzins, Professor
Department of Computer Science
Sponsor: U.S. Army Research Office

OBJECTIVE: The objective of the proposed research is the design of an integrated set of formal models and methods for automating a wide range of design and development tasks for real-time systems. The methods used found on automation of design activities that appear in an evolutionary prototyping approach to software development. This research intends to use the state-of-the-art formal methods in software engineering to construct a cohesive set of formal models. These models are used to create and to unify a computational model to support automated processes for computer aided prototyping. Mathematical models for implementing a set of automated and integrated software tools will also be developed.

This research combines very high level specification abstractions and concepts with formal real-time models, automated management of software design data and human resources, transformations, change merging, and automated retrieval of reusable software components to provide automated methods for generating real-time programs and for coordinating teams of developers. The significance of the research is to improve productivity and software quality by enabling a higher level of automation in software development. The result of this research will broaden the definition of automatic programming and will make automatic programming a practical approach for increasing productivity in the software lifecycle. Automated decision support functions used will ensure software quality by decreasing the human effort required and minimizing the incidence of human error.

The approach controls the complexity and high degrees of freedom of the software process by using computer-aid. Earlier user feedback for validating and refining specifications through trial use of operational system prototypes experimentally ensures that the formal specifications corresponds to user needs. Maintenance costs will be minimized by reducing the need to repair requirements errors after system deployment and by using specification-based automatic program correction methods sensitive to both syntax and semantics.

SUMMARY: This project is investigating formal models that can support automated methods supporting software development. The focus was on automation support for requirements elicitation, particularly for prototyping, and on automation support for software evolution, particularly for automated generation of schedules for hard real-time software, for retrieval of reusable software components, for several modifications to a system, and for using specifications in the design of software architectures.

PUBLICATIONS:

Luqi, "System Engineering and Computer-Aided Prototyping," Journal of Systems Integration, special issue on Computer Aided Prototyping, Vol. 6, No. 1, pp. 15-17, 1996.

Luqi, and Shing, M., "Real-Time Scheduling for a Prototyping Language," Journal of Systems Integration, special issue on Computer-Aided Prototyping, Vol. 6, No. 1, pp. 41-72, 1996.

Goguen, J., Nguyen, D., Meseguer, J., Luqi, Zhang, D., and Berzins, V., "Software Component Search," Journal of Systems Integration, special issue on Computer Aided Prototyping, Vol. 6, No. 2, pp. 93-134, 1996.

Berzins, V., and Dampier, D., "Software Merge: Combining Changes to Decompositions," Journal of Systems Integration, special issue on Computer-Aided Prototyping, Vol. 6, No. 12, pp. 135-150, 1996.

Luqi, Chang, C., and Zhu, H., "Specifications in Software Prototyping," submitted to Journal of Systems and Software.

Shing, M., Berzins, V., and Luqi, "Computer Aided Prototyping System (CAPS)," Proceedings of the Software Technology Conference, Salt Lake City, UT, 21-26 April 1996.

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Luqi, "Specifications in Software Prototyping," Proceedings of the 8th International Conference on Software Engineering and Knowledge Engineering, Lake Tahoe, CA, pp. 189-197, 10-12 June 1996.

Berzins, V., "Recombining Changes to Software Specifications,," Proceedings of the 8th International Conference on Software Engineering and Knowledge Engineering, Lake Tahoe, CA, pp. 136-144, 10-12 June 1996.

Luqi, Berzins, V., Nguyen, D., and Zhang, D., "Multi-Level Filtering for Software Component Retrieval," Proceedings of the 1996 International Conference on Circuits and System Sciences, Shanghai, China, pp. 284-287, 20-25 June 1996.

Rusin, D., Luqi, and Scanlon, M., "SIDS Wireless Acoustic Monitor (SWAM)," Proceedings of the 21st International Conference on Lung Sounds, The International Lung Sounds Association, Chester, England, 4-6 September 1996.

Berzins, V., Luqi, and Shing, M., "Scheduling Real-Time Software Prototypes,," Proceedings of the 2nd International Symposium on Operations Research and Its Applications, Guilin, China, pp. 614-623, 11-13 December 1996.

CONFERENCE PRESENTATIONS:

Luqi, "Multi-Level Filtering for Software Component Retrieval," C.V. Ramamoorthy Workshop on Advances in Computer Science and Engineering, University of California at Berkeley, 4 May 1996.

Luqi, "A Machine-Based Software Engineering Paradigm," Keynote, U.S. Army Research Program Review, Research Triangle, NC, 16-17 May 1996.

Luqi, "Specifications in Software Prototyping," 8th International Conference on Software Engineering and Knowledge Engineering, Lake Tahoe, CA, 10-12 June 1996.

Luqi, Berzins, V., Nguyen, D., and Zhang, D., "Multi-Level Filtering for Software Component Retrieval," 1996 International Conference on Circuits and System Sciences, Shanghai, China, 20-25 June 1996.

Luqi, "Software Architecture for Systematic System Development," Jiaotong University, Shanghai, China, 4 October 1996.

Luqi, "Models, Languages, and Tools for Software Automation," International Technological University, San Jose, CA, 6 November 1996.

Luqi, Berzins, V., "Computer-Aided Prototyping of Real-Time Systems," University of Science and Technology, Hong Kong, 16 December 1996.

THESES DIRECTED:

Hong, R., "User Interface and Database Design," Master's Thesis, Naval Postgraduate School, March 1996.

Nguyen, T., "Populating the Software Database," Master's Thesis, Naval Postgraduate School, March 1996.

Grosenheider, S., "Enhancements for the CAPS Prototyping System Description Language Syntax-Directed Editor," Master's Thesis, Naval Postgraduate School, March 1996.

Irwin, D., "Reengineering of the Computer-Aided Prototyping System for Portability," Master's Thesis, Naval Postgraduate School, September 1996.

Angrisani, D. & Whitbeck, G., "Software System Requirements for the Army Tactical Missile System," Master's Thesis, Naval Postgraduate School, September 1996.

PROJECT SUMMARIES

Cooke, R., "Technology Transfer of Computer Aided Prototyping System," Master's Thesis, Naval Postgraduate School, September 1996.

Ibrahim, O., "A Model and Decision Mechanism for Software Requirements Engineering," Ph.D. Dissertation, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Software engineering, formal methods, automation

MAXIMIZING NETWORK THROUGHPUT VIA AUTONOMOUS AGENT MANAGEMENT

Luqi, Professor

Department of Computer Science

Sponsor: Naval Command Control and Ocean Surveillance Center

OBJECTIVE: The objective of the research is to investigate the feasibility of using autonomous agents in C4I systems to maximize throughput in a constrained tactical radio frequency communications network. The purpose of the auto-agents in the software structure is to realize differential message transmission, so that only the part of the state that has changed since the last communication has to be retransmitted, and to separate this capability from the details of the network protocols and representations to achieve improved interoperability. This technique should provide effective real-time communications in a restricted bandwidth environment.

SUMMARY: This project explored hierarchical object methods for achieving cross network communications while maintaining compatibility with existing standards. We are exploring designs to realize adaptive behavior pattern recognition and progressive learning processes. These techniques are being assessed to determine if they can achieve high RF throughput while maintaining the integrity of the network in real time.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Software engineering, networks

RAPID PROTOTYPING OF HARD REAL-TIME SYSTEMS

Luqi, Professor

Department of Computer Science

Sponsor: National Science Foundation

OBJECTIVE: The goal of this research is to enable rapid prototyping of hard real-time systems via a computer aided prototyping system (CAPS). CAPS is based on a prototyping language with module specifications for modeling real-time systems and combining reusable software. These tools make it possible for prototypes to be designed quickly, to be executed, and to be analyzed for eliciting and validating the requirements. The research focuses on automated methods for retrieving, adapting, and combining reusable components based on normalized module specifications; establishing feasibility of real-time constraints via scheduling algorithms; simulating unavailable components via algebraic specifications; automatically generating translators and -time schedules for supporting execution; constructing a prototyping project database using derived mathematical models; providing automated design completion and error checking facilities in a designer interface; and establishing a convenient graphical interface for design and debugging. This is a continuing project.

SUMMARY: The main research problems are developing abstract models and implementation techniques based on formalized specifications. Progress during this year has been mainly in the areas of automated support for software evolution, multiprocessor models for real-time systems, software transformation and software reuse. In FY96, previously developed methods for hard real-time scheduling were tested and evaluated, developed improved methods for

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evolution of software requirements, computer-aided software reuse and retrieval, software change merging, software architectures, and the use of logic to support software prototyping. These tools together form an integrated software environment CAPS aimed at rapidly prototyping hard real-time embedded software system to support software evolution as well as initial development.

PUBLICATIONS:

Luqi, "System Engineering and Computer-Aided Prototyping," Journal of Systems Integration, special issue on Computer Aided Prototyping, Vol. 6, No. 1, pp. 15-17, 1996.

Luqi, and Shing, M., "Real-Time Scheduling for a Prototyping Language," Journal of Systems Integration, special issue on Computer-Aided Prototyping, Vol. 6, No. 1, pp. 41-72, 1996.

Goguen, J., Nguyen, D., Meseguer, J., Luqi, Zhang, D., and Berzins, V., "Software Component Search," Journal of Systems Integration, special issue on Computer Aided, Vol. 6, No. 2, pp. 93-134, 1996.

Berzins, V., and Dampier, D., "Software Merge: Combining Changes to Decompositions," Journal of Systems Integration, special issue on Computer-Aided Prototyping, Vol. 6, No. 1-2, pp. 135-150, 1996.

Shing, M., Berzins, V., and Luqi, "Computer Aided Prototyping System (CAPS)," Proceedings of the Software Technology Conference, Salt Lake City, UT, 21-26 April 1996.

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Luqi, Berzins, V., Nguyen, D., and Zhang, D., "Multi-Level Filtering for Software Component Retrieval," Proceedings of the 1996 International Conference on Circuits and System Sciences, Shanghai, China, pp. 284-287, 20-25 June 1996.

Rusin, D., Luqi, and Scanlon, M., "SIDS Wireless Acoustic Monitor (SWAM)," Proceedings of the 21st International Conference on Lung Sounds, The International Lung Sounds Association, Chester, England, 4-6 September 1996.

Berzins, V., Luqi, and Shing, M., "Scheduling Real-Time Software Prototypes," Proceedings of the 2nd International Symposium on Operations Research and Its Applications, Guilin, China, pp. 614-623, 11-13 December 1996.

CONFERENCE PRESENTATIONS:

Luqi, "Multi-Level Filtering for Software Component Retrieval," C.V. Ramamoorthy Workshop on Advances in California at Berkeley, CA, 4 May 1996.

Luqi, "A Machine-Based Software Engineering Paradigm," Keynote, U.S. Army Research Program Review, Research Triangle, NC, 16-17 May 1996.

Luqi, "Specifications in Software Prototyping," 8th International Conference on Software Engineering and Knowledge Engineering, Lake Tahoe, CA, 10-12 June 1996.

Luqi, Berzins, V., Nguyen, D., and Zhang, D., "Multi-Level Filtering for Software Component Retrieval," 1996 International Conference on Circuits and System Sciences, Shanghai, China, 20-25 June 1996.

PROJECT SUMMARIES

Luqi, "Software Architecture for Systematic System Development," Jiaotong University, Shanghai, China, 4 October 1996.

Luqi, "Models, Languages, and Tools for Software Automation," International Technological University, San Jose, CA, 6 November 1996.

Luqi, and Berzins, V., "Computer-Aided Prototyping of Real- Time Systems," University of Science and Technology, Hong Kong, 16 December 1996.

THESES DIRECTED:

Hong, R., "User Interface and Database Design," Master's Thesis, Naval Postgraduate School, March 1996.

Nguyen, T., "Populating the Software Database," Master's Thesis, Naval Postgraduate School, March 1996.

Grosenheider, S. "Enhancements for the CAPS Prototyping System Description Language Syntax-Directed Editor," Master's Thesis, Naval Postgraduate School, March 1996.

Irwin, D., "ReEngineering of the Computer-Aided Prototyping System for Portability," Master's Thesis, Naval Postgraduate School, September 1996.

Angrisani, D., Whitbeck, G., "Software System Requirements for the Army Tactical Missile System," Master's Thesis, Naval Postgraduate School, September 1996.

Cooke, T., "Technology Transfer of Computer Aided Prototyping System," Master's Thesis, Naval Postgraduate School, September 1996.

Ibrahim, O., "A Model and Decision Mechanism for Software Requirements Engineering," Ph.D. Dissertation, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Software engineering, formal methods, automation

AN EXPERIMENTAL STUDY OF SOFTWARE ARCHITECTURES AND SOFTWARE REUSE

Robert B McGhee, Professor

Department of Computer Science

A.J. Healey, Professor

Department of Mechanical Engineering

Sponsors: National Science Foundation and Naval Postgraduate School

OBJECTIVE: The goal of this project is to investigate alternative software architectures for control of unmanned underwater vehicles, and to find effective means for archiving and retrieving software modules used to implement such software systems. The research is being conducted in cooperation with the Monterey Bay Aquarium Research Institute (MBARI), and with INRIA, a French Government Research Institute.

SUMMARY: This is a three-year project which began in 1994 and terminates 30 June 1997. During calendar year 1996, much of the work has been focused on further development of the "Rational Behavior Model" (RBM) software architecture, and its testing in the NPS "Phoenix" autonomous underwater vehicle (AUV). This work was successful. In another study, a success test in Monterey Bay on a small AUV navigation system (SANS) based on a combination of a low cost strapped down inertial measurement unit (IMU) was made on a miniaturized global positioning system receiver (GPS). Finally, an advanced "point and click" mission planning software expert system was developed which

PROJECT SUMMARIES

allows mission specialists to automatically generate mission control software without any manual coding. Generalization and improvement of this system to permit execution of a wider range of missions by Phoenix is planned for the next and final year of this project.

PUBLICATIONS:

Byrnes, R.B., Healey, A.J., McGhee, R.B., Nelson, M.L., Kwak, S.H., and Brutzman, D.P., "The Rational Behavior Model Software Architecture for Intelligent Ships: An Approach to Mission and Motion Control," Proceedings of American Society of Naval Engineers, Vol. 108, No. 2, pp. 43-55. March 1996.

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Marco, D.B., Healey, A.J., and McGhee, R.B., "Autonomous Underwater Vehicles: Hybrid Control of Mission and Motion," Journal of Autonomous Robots, Vol. 3, pp. 169-186, October 1996.

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Brutzman, D., Burns, M., Campbell, M., Davis, D., Healey, A., Holden, M., Leonhardt, B., Marco, D., McClarin, D., McGhee, R., and Whalen, R., "NPS Phoenix AUV Software Integration and Open Water Testing," Proceedings of IEEE AUV'96 Symposium, Monterey, CA, pp. 99-108, June 1996.

Healey, A.J., Marco, D.B., Oliveira, P., Pascoal, A., Silva, V., and Silvestre, C., "Strategic Level Mission Control - An Evaluation of CORAL and Prolog Implementations for Mission Control Specifications," Proceedings of IEEE AUV'96 Symposium, Monterey, CA, pp. 125-134, June, 1996.

Marco, D.B. and Healey A.J., "Local Area Navigation Using Sonar Feature Extraction and Model Based Predictive Control," Proceedings IEEE AUV'96 Symposium, Monterey, CA, pp. 67-77, June 1996.

McMillan, S., Orin, D.E., and McGhee, R.B., "A Computational Framework for Simulation of Underwater Robotic Vehicle Systems," Journal of Autonomous Robots, Vol 3, pp. 253-268, October 1996.

Bachmann, E.R., McGhee, R.B., Whalen, R.H., Steven, R., Walker, R.G., Clynych, J.R., Healey, A.J., and Yun, X.P., "Evaluation of an Integrated GPS/INS System for Shallow-Water AUV Navigation (SANS)," Proceedings of IEEE AUV'96 Conference, Monterey, CA, pp. 268-275 June 1996.

Davis, D.T., Brutzman, D.P., Leonard, B.J., and McGhee, R.B., "Operational Mission Planning and Mission Control for the Phoenix Autonomous Underwater Vehicle," accepted for publication in IEEE Journal of Oceanic Engineering, 1997.

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Leonard, B.J., "Mission Planning and Mission Control Software for the Phoenix Autonomous Underwater Vehicle (AUV): Implementation and Experimental Study," Master's Thesis, Naval Postgraduate School, March 1996.

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McClarín, D.W., "Discrete Asynchronous Kalman Filtering of Navigation Data for the Phoenix Autonomous Underwater Vehicle," Master's Thesis, Naval Postgraduate School, March 1996.

Steven, R., "Simulation-Based Validation of Navigation Filter Software for a Shallow Water AUV Navigation System," Master's Thesis, Naval Postgraduate School, March 1996.

Walker, R.G., "Design and Evaluation of an Integrated, Self-Contained GPS/INS Shallow-Water AUV Navigation System (SANS)," Master's Thesis, Naval Postgraduate School, June 1996.

Davis, D.T., "Precision Control and Maneuvering of the Phoenix Autonomous Underwater Vehicle for Entering a Recovery Tube," Master's Thesis, Naval Postgraduate School, September 1996.

Burns, M.L., "Merging Virtual and Real Execution Level Control Software for the Phoenix Autonomous Underwater Vehicle," Master's Thesis, Naval Postgraduate School, September 1996.

Marco, D.B., "Autonomous Control of Underwater Vehicles and Local Area Maneuvering," Ph.D. Dissertation, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Other (Military Robotics)

KEYWORDS: Robotics, mine countermeasures, autonomous underwater vehicles (AUV)

NPSNET: JANUS SOLDIER STATION - PHASES 1 AND 2

David R. Pratt, Assistant Professor

Department of Computer Science

Sponsor: U.S. Army Training and Doctrine Analysis Command

OBJECTIVE: The focus of this project is the integration of the JANUS combat model routines into NPSNET to produce a single integrated system. This project will leverage off existing and supporting Janus research efforts.

SUMMARY: This statement of work is for the development of software for a graphics system that will serve as a prototype computer terminal for a soldier station. The soldier station will allow for the realism that is not currently available in the constructive models that are in U.S. Army inventory and will attempt to bridge the gap between a wholly constructive model, e.g., Janus, and total immersion virtual reality. The final prototype will be an independent station that will be linked and interact with the Janus combat model and other DIS 2.0.3/2.0.4 systems. Two systems will be built, one each at the TRADOC Analysis Center-White Sands Missile Range (TRAC-WSMR), New Mexico and The Department of Computer Science, Naval Postgraduate School, Monterey, CA. The hardware and third party software needed for the system located at TRAC-WSMR will be funded separately. The specific requirements for this station are specified elsewhere in this document. The foremost areas of interest in development of the soldier station are the analysis areas of command, control (C2) and situational awareness. Realism in the terrain representation, movement, visual parameters and others listed further in this document are required at moderate levels of detail.

Additionally, a prototype database will have to be converted from the Janus format to a format that is suitable for visualization. The vision is to develop a tool, or series of tools, that will convert the Janus terrain databases into format that can be used by NPSNET. While not the main focus of this research, this is a necessary step to ensure the success of the project.

CONFERENCE PRESENTATIONS:

Pratt, S., Pratt, D., Rieger, L., and Jackson, L., "Implementation of the IS Group of PDU for Network Bandwidth Reduction," Proceedings of the 15th DIS Workshop, Orlando, FL, September 1996.

PROJECT SUMMARIES

Pratt, David. R., "Next Generation Computer Generated Forces," Proceedings of the Sixth Conference on Computer Generated Forces and Behavioral Representation, Orlando, FL, 23-25 July 1996.

Pratt, S., Pratt, D., Ohman, D., and Galloway, J., "Soldier Station: Integrating Constructive and Virtual Models," Proceedings of the Sixth Conference on Computer Generated Forces and Behavioral Representation, Orlando, FL, 23-25 July 1996.

Pratt, S.M. and Pratt, D.R., "Use of the IS Part of PDU for Unit Aggregation: Preliminary Report," Proceedings of the 14th DIS Workshop, Orlando, FL, 11-15 March 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Manpower, Personnel and Training

KEYWORDS: Combat models, graphics, synthetic environments, artificial intelligence, computer networks

NPSNET: INDIVIDUAL PORTAL INTEGRATION/SUPPORT FOR AUSA 96

David R. Pratt, Assistant Professor

Department Computer Science

Sponsor: U.S. Army Research Office

OBJECTIVE: This project deals with the integration of a new motion platform for simulation of individual motion through the virtual environment. This proposal covers the Association of the United States Army (AUSA) demonstration and Warrior Network: integrating the ODT, integrating DI-Guy, interfacing with the Land Warrior Folks, upgrading fully to DIS 2.0.4.

SUMMARY: The dream of being able to step into another world has been partially realized by the creation of virtual environments (VEs) and the ability to place virtual humans in them. Human figures in synthetic environments have appeared in many arts and entertainment applications and human factors applications. However, usually the number of participants is small, or the figures consist of simple real-time representations with very limited capabilities, or the VE does not support real-time interactivity. Simulation of humans in large-scale, interactive VEs requires computational resources which can exceed the capabilities of existing computers. Optimal system design and performance issues must be considered in order to support such simulations.

Large computational resources are needed to represent multiple realistic human figures, render detailed environments, and manage real-time interactions. Realistic simulation of humans involves the use of high resolution models with numerous joints; animation of realistic human motions itself is a difficult problem which requires strong computational capabilities. Since the natural metric for human length is a foot, VEs should be perceptually rich in depth and distance. Many small objects and textures with small characteristic pattern sizes should be present in order to effectively navigate through them. For realism, the VEs should be dynamic and allow real-time interactions with objects and multiple participants. Input devices should be intuitive for the users to operate and highly responsive.

With networked VEs, users on separate machines can each view the representation of a shared virtual world and interact with one another. But, there are additional problems which must be solved in order for networked VE interactions to take place effectively. These include how to maintain virtual world consistency, how to efficiently distribute information across the network, and how to represent remote dynamic entities which are constantly moving in an unpredictable manner. This paper describes the efforts to develop a system which successfully simulates multiple interactive humans in large-scale, networked VEs. Some well known solutions have been implemented to the previously mentioned problems along with some creative new ideas into Naval Postgraduate School's Networked Simulator (NPSNET), a research test bed for the design, development and implementation of networked VE components at the Association of the United States Army Conference in Washington DC.

The Naval Postgraduate School and SARCOS Research Corporation demonstrated the interconnection of two different human mobility platforms with sensed upper bodies, a stick and throttle controlled human figure, and ModSAF based human icons. Of these varied control paradigms, one mobility platform was located remotely in Fort Benning,

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Georgia and the rest were at the conference. Communications with the remote entity was done over the Distributed Simulation Internet. Local communication was done via a three tiered hierarchical network scheme, the top two layers using the Distributed Interactive Simulation protocols. The lowest level protocol is device dependent.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Manpower, Personnel and Training

KEYWORDS: Combat models, graphics, synthetic environments, artificial intelligence, computer networks

TECHNICAL SUPPORT FOR THE JOINT SIMULATION SYSTEMS JOINT PROGRAM OFFICE (JSIMS JPO)

David R. Pratt, Assist Professor
Department of Computer Science

Sponsor: Joint Simulation Systems Joint Program Office

OBJECTIVE: This proposal funds the position of the Technical Director for the JSIMS Joint Program Office. In this capacity, Dr. Pratt has been responsible for overall technical direction of the program.

SUMMARY: JSIMS is the leading DoD Modeling and Simulation (M&S) program to provide a next generation capability for training and mission rehearsal. The role of the Joint Program Office is to provide the simulation architecture, representation of Joint functionality, and overall technical and implementation direction for the JSIMS family of programs. The Services and DoD agencies are tasked to provide the representations of their respective warfare domains. The overall JSIMS program budget exceeds \$500M making it one of the largest and most ambitious M&S efforts undertaken by DoD.

David R. Pratt is the first Technical Director of the Joint Simulation System (JSIMS) and coordinates with senior DoD and industry leadership to manage new technology infusion. Part of the duties, is helping to set up and define new DARPA and DMSO research programs and actively help to set the future direction of DoD's M&S efforts. This position is for two years (January 1996 to December 1997). The goal is to bring back to NPS valuable knowledge and contacts to help the school stay relevant to DoD.

CONFERENCE PRESENTATION:

Pratt, D.R., "Next Generation Computer Generated Forces," Proceedings of the Sixth Conference on Computer Generated Forces and Behavioral Representation, Orlando, FL, 23-25 July 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Manpower, Personnel and Training

KEYWORDS: Combat models, graphics, synthetic environments, artificial intelligence, computer networks

TERRAIN AND COMMAND AND CONTROL VISUALIZATION

David R. Pratt, Assistant Professor
Department of Computer Science

Sponsor: Naval Command, Control and Ocean Surveillance Center

OBJECTIVE: The purpose of this project was to incorporate human factors and advanced visualization techniques in to NPSNET to support the ARPA LeatherNet project. The main function of the LeatherNet system is to aid the Marine Corps in mission planning and after action reviews. This project has been demonstrated to the Commandant of the Marine Corps, and the Secretaries of Navy and Defense.

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SUMMARY: As the importance of simulations increases in military training and operations, the need for an simple, efficient method to manage, distribute, and visualize the environment becomes critical. This research project was taken to establish an infrastructure that is capable of addressing this need. After an evaluation of some of the critical problems facing this community, a three prong approach was undertaken. First was to gather, evaluate, and archive the selected database and formats. As part of this process, several software converters were written to visually compare the terrain. From this process, a new run time format was settled on that supports a solution to the second problem. The second main problem is that of the real time management of a large scale high fidelity and resolution terrain database. Rather than implement a new redundant format, the MAPS lab at CMU was used in the fielding of the Tiled Scene Graph (TSG) terrain format. This format allows for rapid paging of the terrain, allowing for almost an unlimited play box size. The third focus is that of data standards. To this end, the investigation has been active in the Synthetic Environment Data Interchange Standard (SEDRI) effort. By being part of this process, valuable insight is gained into the needs of the community and influences the solutions for the next generations of military Modeling and Simulation (M&S) efforts.

PUBLICATIONS:

Pratt, S., Pratt, D., Rieger, L., and Jackson, L., "Implementation of the IS Group of PDU for Network Bandwidth Reduction," Proceedings of the 15th DIS Workshop, Orlando, FL, September 1996.

Pratt, D.R., "Next Generation Computer Generated Forces," Proceedings of the Sixth Conference on Computer Generated Forces and Behavioral Representation, Orlando, FL, 23-25 July 1996.

Pratt, S., Pratt, D., Ohman, D., and Galloway, J., "Soldier Station: Integrating Constructive and Virtual Models," Proceedings of the Sixth Conference on Computer Generated Forces and Behavioral Representation, Orlando, FL, 23-25 July 1996

Pratt, S.M. and Pratt, D.R. "Use of the IS Part of PDU for Unit Aggregation: Preliminary Report," Proceedings of the 14th DIS Workshop, Orlando, FL, 11-15 March 1996

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Manpower, Personnel and Training

KEYWORDS: Combat models, graphics, synthetic environments, artificial intelligence, computer networks

INTELLIGENT ACCESS TO A DATABASE OF MILITARY PHOTOGRAPHS

Neil C. Rowe, Associate Professor

Department of Computer Science

Sponsor: U.S. Army Artificial Intelligence Center

OBJECTIVE: To develop a system for natural-language access to a large library of photographs from a military test facility. Fast parallel search methods were explored using the concept of "information filtering."

SUMMARY: In FY96 the coverage of the project to extract captioned photographs from the World Wide Web was expanded, since the eventual goal is to extract photographs in textual context. An increasing number of captioned photographs are quickly accessible from the Web, including some good ones available from the primary test site of NAWC-WD, which was supplemented with some additional photographs related to Navy and Army topics that were found in topic-restricted searches on the Web. The first technical challenge was to distinguish the photographs from the graphics, since both are stored similarly. Some properties were identified quickly calculable from a quick image analysis that could identify photographs with 85% success.

Another technical challenge was to find the captions associated with the photographs, since there is not much consistency in the size, placement, typographic style, or syntax of captions. A hybrid of techniques was developed from

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both neural networks and conventional artificial intelligence to rate potential captions. After training, captions could be identified with 41% success when the inferred likelihood the image was a photograph was used, although only 2% of the total text on the test pages were captions.

The work continues on the design of a parallel-processing implementation of the information filtering in the system, and developing new modeling methods for handling uncertainty in filter performance.

PUBLICATIONS:

Rowe, N.C., "Using Local Optimality Criteria for Efficient Information Retrieval with Redundant Information Filter," ACM Transactions on Information Systems, Vol. 14, No. 2, pp. 138-174, April 1996.

Guglielmo, E.J., and Rowe, N.C., "Natural Language Retrieval of Images Based on Descriptive Captions," ACM Transactions on Information Systems, Vol. 14, No. 3, pp. 237-267, May 1996.

Rowe, N.C., "Efficient Parallel Information Filtering," 1996 Command and Control Research and Technology Symposium, Monterey CA, pp. 413-414, June 1996.

CONFERENCE PRESENTATIONS:

Rowe, N.C., "The MARIE Project: A Testbed for Military AI Natural-Language and Vision Techniques," Presentation at Army Artificial Intelligence Center PROPCON96 Conference, Washington DC, June 1996.

Rowe, N.C., "An Intrusion-Detection Simulator/Tutor," Presentation at Workshop on Intrusion Detection, 12th Computer Security Applications Conference, San Diego, CA, December 1996.

OTHER:

Software for finding captions on World Wide Web pages as described above.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human System Interface

KEYWORDS: Images, captions, digital libraries, information filtering, content analysis

IMAGE PROCESSING OF NAVAL PHOTOGRAPHS FOR RETRIEVAL

Neil C. Rowe, Associate Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: To develop a system for natural-language access to a large library of photographs from a military test facility. Fast parallel search methods were explored using the concept of "information filtering."

SUMMARY: In FY96 the coverage of the project to extract captioned photographs from the World Wide Web was expanded, since the eventual goal is to extract photographs in textual context. An increasing number of captioned photographs are quickly accessible from the Web, including some good ones available from the primary test site of NAWC-WD, which was supplemented with some additional photographs related to Navy and Army topics that were found in topic-restricted searches on the Web. The first technical challenge was to distinguish the photographs from the graphics, since both are stored similarly. Some properties were identified quickly calculable from a quick image analysis that could identify photographs with 85% success.

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PROJECT SUMMARIES

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Guglielmo, E.J., and Rowe, N.C., "Natural Language Retrieval of Images Based on Descriptive Captions," ACM Transactions on Information Systems, Vol. 14, No. 3, pp. 237-267, May 1996.

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CONFERENCE PRESENTATIONS:

Rowe, N.C., "The MARIE Project: A Testbed for Military AI Natural-Language and Vision Techniques," Presentation at Army Artificial Intelligence Center PROPCON96 Conference, Washington DC, June 1996.

Rowe, N.C., "An Intrusion-Detection Simulator/Tutor," Presentation at Workshop on Intrusion Detection, 12th Computer Security Applications Conference, San Diego, CA, December 1996.

OTHER:

Software for finding captions on World Wide Web pages as described above.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human System Interface

KEYWORDS: Images, captions, digital libraries, information filtering, content analysis

ARTIFICIAL INTELLIGENCE FOR TERRAIN-DATABASE INTEGRATION

Neil C. Rowe, Associate Professor

Department of Computer Science

Sponsor: U.S. Army Training and Doctrine Analysis Command (TRADOC) Analysis Command

OBJECTIVE: To develop an intelligent interface to help construct integrated terrain databases by putting together existing simpler databases. The interface will assist the user by analyzing the many options and suggesting the best ones.

SUMMARY: This was a six-week project to develop some prototype software. The software has knowledge of particular terrain data sources and their properties. It studies the combinations and ranks them heuristically, and then attempts to get confirmation via questions to the user on the details of a proposal. If the user disagrees with the recommendations, the software tries other options, and so on. The system can also infer user constraints not explicitly stated. In FY96 the software was successfully implemented and a paper was written.

PUBLICATIONS:

Rowe, N.C., "An Intelligent Assistant for Construction of Terrain Databases," Naval Postgraduate School, Technical Report, September 1996.

PROJECT SUMMARIES

OTHER:

Software for integration of terrain databases, September 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human-System Interfaces

KEYWORDS: Integrated terrain databases

THE GEOLOCATION WORKBENCH

H. Loomis, Professor

Department of Electrical and Computer Engineering

T. Shimeall, Associate Professor

Department of Computer Science

Sponsor: Navy Tactical Exploitation of National Capabilities (TENCAP) Office

OBJECTIVE: To initiate the development of a programming environment for geolocation algorithms.

SUMMARY: This ongoing research project involves the development of a MATLAB-based programming and testing environment for geolocation algorithms. The initial work done thus far involves setting of requirements, design of a prototype user interface, development of candidate algorithms to be studied in the workbench and development of a common signal format to permit ease of comparison between differing algorithms.

THESES DIRECTED:

Jones, Brian, K., "Geolocation Workbench Development System," Master's Thesis, Naval Postgraduate School, September 1996.

Jenik, Douglas, A., "Time-Difference-of-Arrival Estimation Using Cyclostationary Signal Processing Techniques," Master's Thesis, Naval Postgraduate School, March 1996.

Jones, Gregory, I., "Design and Implementation of a Geolocation Software Workbench," Master's Thesis, Naval Postgraduate School, March 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Geolocation algorithms

A STUDY OF IMAGE DECLASSIFICATION POLICIES

T. Shimeall, Associate Professor

C. Irvine, Assistant Professor

D.M. Volpano, Assistant Professor

Department of Computer Science

Sponsor: Central Imagery Office

OBJECTIVE: To study image declassification policies in order to develop tools and methods for formally assessing these policies.

SUMMARY: This research involved extensive analysis of imagery data formats, current declassification rules and discussions with CIO personnel to identify and categorize issues involved in automatic declassification of images and their associated annotation data. The policies involved in the declassification of imagery and the formats used in imagery data were found to match the problem of automatic image declassification with the problem of token recognition

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and categorization. Token recognition and categorization is known to be expressible by regular expressions. Regular expressions are an abstract class of notations that would permit the proof of a number of desirable properties including completeness, consistency, subsetting and compliance with regulations. This research, however, ceased with the matching of imagery declassification and token recognition; further effort is needed to establish the proof system.

THESIS DIRECTED:

Fulp, John, D., "A National Imagery System Security Policy," Master's Thesis, Naval Postgraduate School, March 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Imagery declassification, token recognition

ON-LINE POLYMORPHIC TYPE INFERENCE

Dennis M. Volpano, Assistant Professor

Department of Computer Science

Sponsor: National Science Foundation

OBJECTIVE: This work is part of a continuing project whose primary objective is to investigate new type theories for imperative programming languages.

SUMMARY: An ML-style polymorphic type system was designed for a dialect of C, called Polymorphic C. It has the same pointer operations as C, including the address-of and dereferencing operators, and pointer arithmetic. The type system allows these operations in their full generality, so that programmers need not give up the flexibility of C to gain the benefits of ML-style polymorphism and rigorous type reconstruction. A type soundness theorem was proved that gives a rigorous and useful characterization of well-typed Polymorphic C programs in terms of what can go wrong when they are evaluated. This theorem, called a progress theorem, required developing a new style of semantics. This style has shown to be effective in proving a wide variety of other properties in unrelated type systems.

PUBLICATIONS:

Smith, G. and Volpano, D., "Towards an ML-style Polymorphic Type System for C," Proceedings 1996 European Symposium on Programming, Lecture Notes in Computer Science, Vol. 1058, pp. 341-355, April 1996.

Smith, G. and Volpano, D., "Polymorphic Typing of Variables and References," ACM Transactions on Programming Languages and Systems, Vol. 18, No. 3, pp. 254-267, May 1996.

Volpano, D., "Lower Bounds on Type Checking Overloading," Information Processing Letters, Vol. 57, No. 1, 15 January 1996.

THESIS DIRECTED:

Ozgen, Mustafa, A., "Type Inference Algorithm and Transition Semantics for Polymorphic C," Master's Thesis, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Programming languages, semantics, static analyses

PROJECT SUMMARIES

AN ENVIRONMENT FOR DEVELOPING SECURE SOFTWARE

Dennis M. Volpano, Assistant Professor

Cynthia Irvine, Assistant Professor

Department of Computer Science

Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: The primary objective of this project is to develop algorithms capable of statistically analyzing code, targeted for remote execution, for secure flow violations. The algorithm will attempt to construct a proof, for a given program, in a sound flow logic, thereby establishing the program is secure. The algorithm will permit remote code, written in Web-based languages like Java and JavaScript, to be analyzed prior to execution in order to determine whether it can be executed safely.

SUMMARY: The project aims to incrementally develop a secure flow logic for a deterministic, imperative programming language. The PIs are starting with a logic that characterizes the early work in secure flow static analysis by Dorothy Denning. The idea is to treat secure-flow analysis as a form of type checking in the context of subtypes. Types correspond to security levels and upward flows between levels are modeled naturally by subtyping. There is a notion of procedural polymorphism that arises when the body of a procedure does not fix the security level of a formal parameter. A type checker in this setting corresponds to a flow checker. Viewing flow analysis in this way affords an opportunity to apply powerful and well-understood type inference techniques. Flow hypotheses that the flow checker finds are necessary to prove a program secure in the logic are inferred automatically. They manifest themselves as subtype constraints in a principal type scheme inferred for the program. This has an advantage over Denning-style flow checking, and other more recent proposals, in that this form of flow analysis can be applied to legacy code without requiring the code to be annotated or modified in any way.

PUBLICATIONS:

Volpano, D., Irvine C., and Smith, G., "A Sound Type System for Secure Flow Analysis," Journal of Computer Security, Vol. 4, No. 3, pp. 1-21, December 1996.

Volpano, D. and Smith, G., "On the Systematic Design of Web Languages," ACM Computing Surveys, Vol. 28, No. 2, pp. 315-317, June 1996.

CONFERENCE PRESENTATIONS:

Volpano, D., "Provably-Secure Programming Languages for Remote Evaluation," Workshop on Strategic Directions in Computing Research, Massachusetts Institute of Technology, Cambridge, MA June 1996.

Volpano, D., "Type Systems for Secure Remote Evaluation," 12th Mathematical Foundations of Programming Semantics, Boulder, CO, June 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Secure information flow, web languages

TYPE SYSTEMS FOR SECURE REMOTE EVALUATION

Dennis Volpano, Assistant Professor

Department of Computer Science

Sponsor: National Science Foundation

OBJECTIVE: The projects aims to investigate the role of programming language design and type systems in ensuring the security of servers in remote evaluation systems. The long-term objective is to develop static analyses, within the context of type systems, to ensure that remotely-evaluated code does not violate a server's privacy or integrity.

PROJECT SUMMARIES

SUMMARY: There is no progress to summarize at this time since the project had a late start in 1996.

DoD KEY TECHNOLOGY AREAS: Computing and software

KEYWORDS: Type systems, remote evaluation, security

DESIGN AND IMPLEMENTATION OF AFAST II (AIRPAC FINANCIAL ANALYSIS TOOL)

C. Thomas Wu, Associate Professor

John Falby, Senior Lecturer

Department of Computer Science

Sponsor: Naval Air Force - Pacific

OBJECTIVE: The objective of this research project is to develop a financial information system capable of providing timely, accurate, and consistent financial information for the AIRPAC. The first AFAST (AIRPAC Financial Analysis Tool) built for this purpose has met the objectives only partially. The system has many limitations, which must be rectified in order for the system to be usable in a highly data-intensive, client-server environment. One of the major reasons for its limitation is due to the poorly designed database. It is proposed to redesign the database and implement an improved version of the AFAST system.

SUMMARY: The AFAST database was completely redesigned. Entity-relationship diagram was developed and full third-normal form relations were implemented. Two separate software systems were implemented. The first system AFAST II was to be used by the endusers. The second system AFAST II Maintenance Module was to be used by the database administrator. Database system was implemented using Borland Interbase. Two software systems-AFAST II and AFAST II Maintenance Module-were developed using Borland Delphi Version 2.0. The system development is ongoing and the plan is to complete both systems by the end of FY97.

OTHER:

Software (AFAST II and AFAST II Maintenance Module)

THESIS DIRECTED:

Gonzalez, M. J., and Hayes, M. R., "The Development of a Relational Database to Support the Flight Hour Program of Commander, Naval Air Forces Pacific," Master's Thesis, Naval Postgraduate School, June 1996.

DoD KEY TECHNOLOGY: Computing and Software, Human Systems Interfaces

KEYWORDS: Database, query languages, data modeling, client/server architecture

NETWORK SUPPORT FOR MULTIMEDIA APPLICATIONS

Geoffrey Xie, Assistant Professor

Department of Computer Science

Sponsor: Naval Postgraduate School

OBJECTIVE: The goal of this research is to design networks that guarantee application-level quality of services (QoS) to multimedia applications. The current focus is on guaranteed statistical service, which is characterized by (1) loss rate of application-level data units (e.g., pictures for video applications) being the performance measure, (2) loss performance guarantees that are fair and measured at small time scales, and (3) a simple and realistic traffic model that promotes statistical multiplexing in the network.

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SUMMARY: First, a new traffic model was developed for real-time variable bit rate (VBR) traffic. Specifically, the sequence of packets for a particular session (called a flow) is modeled as a sequence of bursts, each of which is a sequence of packets that carry an application data unit. The first packet of each burst carries information on the burst (e.g., its bandwidth requirement). Based on this model, a class of burst scheduling networks was designed to provide bounded-delay burst transfer service. By integrating the concepts burst scheduling and ATM block transfer, An admission control algorithm was designed that enables a switch/router to provide the following service: bounded-delay burst transfer at a specified rate of burst losses. In the past year, two efficient implementation techniques were also developed for scheduling real-time traffic: group priority and adaptive heap.

PUBLICATIONS:

Lam, S.S., and Xie, G.G., "Group Priority Scheduling," Proceedings of IEEE INFOCOM '96, San Francisco, CA, March 1996, (to appear in IEEE/ACM Transactions on Networking).

Xie, G.G., and Lam S.S., "An Efficient Adaptive Search Algorithm for Scheduling Real-Time Traffic," Proceedings of 1996 IEEE International Conference on Network Protocols (ICNP '96), Columbus, OH, October 1996.

Xie, G.G., and Lam S.S., "Burst QoS in Broadband Networks," Proceedings of 7th Maryland Workshop on Very High Speed Networks, UMBC, MD, November 1996.

CONFERENCE PRESENTATIONS:

Lam, S.S., and Xie, G.G., "Group Priority Scheduling," IEEE INFOCOM '96, San Francisco, CA, March 1996.

Lam, S.S., and Xie, G.G., "End-to-End QoS Support for Multimedia Applications," 1996 Washington University Workshop on Gigabits Switching, St. Louis, MO, April 1996.

Xie, G.G., and Lam S.S., "An Efficient Adaptive Search Algorithm for Scheduling Real-Time Traffic," 1996 IEEE International Conference on Network Protocols, Columbus, OH, October 1996.

Xie, G.G., and Lam S.S., "Burst QoS in Broadband Networks," 7th Maryland Workshop on Very High Speed Networks, UMBC, MD, November 1996.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Computing and Software

KEYWORDS: Network, multimedia, quality of service (QoS), real-time

PUBLICATIONS/PRESENTATIONS

JOURNAL PAPERS

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- Berzins, V. and Luqi, "Software Evolution in Prototyping," Chinese Journal of Advanced Software Research, 1996.
- Darken, R.P., and Sibert, J.L., "Navigating Large Virtual Spaces," The International Journal of Human-Computer Interaction, Vol. 8, No. 1, pp. 49-72, 1996.
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- Guglielmo, E.J. and Rowe, N.C., "Natural Language Retrieval of Images Based on Descriptive Captions," ACM Transactions on Information Systems, Vol. 14, No. 3, pp. 237-267, May 1996.
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- Lewis, T., "Alice in Wired World: Wonderland or Wasteland?" Computer, Vol. 29, No. 7, pp. 17-19, July 1996.
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- Lewis, T., "Netstorms: The Crash of '96," Computer, Vol. 29, No. 11, pp. 12-14, November 1996.
- Lewis, T., "Software Architectures: Divine Plan or Digital Darwinism?" Computer, Vol. 29, No. 8, pp. 13-15, August 1996.
- Lewis, T., "The Big Software Chill," Computer, Vol. 29, No. 3, pp. 12-14, March 1996.
- Lewis, T., "The Limits of Innovation," Computer, Vol. 29, No. 4, pp. 7-9, April 1996.
- Lewis, T., "The NC Phenomena: Scenes from Your Living Room," Computer, Vol. 29, No. 2, pp. 8-10, February 1996.
- Lewis, T., "The Next 10,000-2 Years: Part I," Computer, Vol. 29, No. 4, pp. 64-70, April 1996.
- Lewis, T., "The Next 10,000-2 Years: Part II," Computer, Vol. 29, No. 5, pp. 78-86, May 1996.
- Lewis, T., "Tools for Building Wired World," Computer, Vol. 29, No. 6, pp. 12-15, June 1996.
- Lewis, T., "Will Tiny Beans Conquer the World Again?," Computer, Vol. 29, No. 9, pp. 13-14, September 1996.
- Luqi, "System Engineering and Computer-Aided Prototyping," Journal of Systems Integration, special issue on Computer Aided Prototyping, Vol. 6, No. 1-2, pp. 15-17, 1996.
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1996 THESIS ABSTRACTS

SOFTWARE SYSTEM REQUIREMENTS FOR THE ARMY TACTICAL MISSILE SYSTEM (ATACMS) END-TO-END SYSTEM USING THE COMPUTER AIDED PROTOTYPING SYSTEM(CAPS) MULTI-FILE APPROACH

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The Department of Defense (DoD) is seeking software system requirements for the Army Tactical Missile System (ATACMS) End-to-End System, which comprises both ATACMS and all sensors, links, and command centers which enable integration across system and service boundaries. The complexity, multiple interfaces, and joint nature of planned ATACMS operations demands accurate specification of software system requirements. DoD also desires automated tools capable of developing rapid prototypes to assist in system definition and reduce system risk.

The goals of this thesis are to provide a rigorous model which can be utilized to validate current specifications, and, to demonstrate CAPS on a large scale project. Accomplishment of these two would provide a needed corroboration of the ATACMS specification, as well as move CAPS out of the purely academic environment.

The result of this thesis is mixed. Due to a paucity of data from which to derive the requirements, the model is generic in nature and is in need of significant customer evaluation, which is not forthcoming. However, CAPS demonstrated its fundamental concept within the bounds of the project, with refinements in code generation, interface, and graphics either incorporated or identified. CAPS is ready for use on an actual project by an experienced team of systems analysts.

THE DESIGN AND IMPLEMENTATION OF A COMPILER FOR THE OBJECT-ORIENTED DATA MANIPULATION LANGUAGE

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Object-oriented relationships, such as inheritance and covering can not be readily incorporated in classic data models. This thesis addresses this problem by the design and implementation of an object-oriented data model (O-ODM), that incorporates the object-oriented paradigm.

A Multimodel and Multilingual Database System called M²DBS has been developed at the Naval Postgraduate School. This system incorporates the classic database data models along with a recently developed object-oriented data model (O-ODM). The problem addressed by this work is to design a new object-oriented data manipulation language (O-ODML) for the O-ODM. The approach is to develop and construct an O-ODML Compiler. Then assimilate the compiler with the Kernel Mapping System (KMS) of the M²DBS.

The result of this thesis is a compiler for the O-ODML of the O-ODM. This O-ODML compiler takes an O-ODM query converts it into a low level intermediate language before translating it into a format that the Real Time Monitor can execute on the M²DBS.

1996 THESIS ABSTRACTS

HEADPHONE-DELIVERED THREE DIMENSIONAL SOUND IN NPSNET

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The current MIDI-based sound system for the distributed virtual environment of NPSNET can only generate aural cues via loudspeaker delivery in two dimensions. To further increase the sense of immersion experienced in NPSNET, a sound system is needed which can generate aural cues via headphone delivery in three dimensions.

The approach taken was to explore the different feasible methods of rendering and presenting headphone-delivered spatial sound. One alternative was to implement a sound server capable of the real-time rendering of three dimensional sounds. Another alternative was to create a library of pre-recorded positioned sound files. In software, new algorithms were developed to integrate the sound server into NPSNET and to provide a table lookup capability for NPSNET's new spatial sound file library.

The result of this research is a sound server capable of rendering up to twenty-four simultaneous sounds for a single participant in NPSNET using "off-the-shelf" sound equipment and computer software. This sound server was tested during numerous demonstrations of NPSNET. This research provided another method of increasing a participant's level of immersion in NPSNET through the use of aural cues.

PORTING HIGH QUALITY GRAPHICS SIMULATIONS TO A LOW-COST COMPUTER ARCHITECTURE

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Two disadvantages of using Silicon Graphics®, Inc. (SGI) computers and SGI's IRIS® Performer™ application programming interface (API) in NPSNET are the current inability to run the graphic simulations on more popular environments, such as personal computer (PC) operating systems (OSs), and the increased expense associated with the alternative of choosing graphics specific hardware over lower cost PCs. Work detailed in this thesis addresses these problems by porting graphics code from NPSNET to relatively inexpensive PC hardware running the Microsoft® Windows NT™ OS.

Two independent approaches were taken. The first created a library of graphics calls which simulate the syntax and functionality of Performer calls, but which have been redefined in terms of the Gemini Technology Corporation's OpenGVS™ API, which is capable of running on the NT platform. The second proposed and implemented a prototype graphics display manager coded using only OpenGVS, rather than Performer, for a proposed platform-independent redesign of NPSNET.

As a result of this effort, the goal of porting IRIS Performer graphics simulations to the PC has been accomplished, and a new architecture for NPSNET display managers has been validated.

1996 THESIS ABSTRACTS

MERGING VIRTUAL AND REAL EXECUTION LEVEL CONTROL SOFTWARE FOR THE PHOENIX AUTONOMOUS UNDERWATER VEHICLE

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The Naval Postgraduate School (NPS) is developing an AUV, Phoenix. The Phoenix has the capability of precise navigation, however too much time is needed to validate a new section of code. NPS is also developing a virtual AUV, which has the capability of being networked, having flexible missions, and having a quick feedback of results when validating new portions of code. The virtual AUV has a drawback of never being tested for real world precision. This thesis discusses the steps taken to combine these two sets of control code to obtain the maximum functionality that will drive either the virtual or actual AUV and produce a faster feedback response to newly developed code.

As a result of this effort, the newly developed control code has successfully driven both the actual and virtual AUVs and provides a means for readily validating new code. Also this new control code has given the AUV research group the ability to perform distributed software development, test all AUV hardware from either the onboard or offboard computers, conduct flexible missions, and test missions in the virtual world prior to conducting them with the AUV.

IMPLEMENTATION AND EFFICIENCY OF STEGANOGRAPHIC TECHNIQUES IN BITMAPPED IMAGES AND EMBEDDED DATA SURVIVABILITY AGAINST LOSSY COMPRESSION SCHEMES

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The term steganography is descriptive of techniques used to covertly communicate by embedding a secret message within an overt message. Such techniques can be used to hide data within digital images with little or no visible change in the perceived appearance of the image and can be exploited to covertly export sensitive information. This thesis explores the data capacity of bitmapped image files and the feasibility of devising a coding technique which can protect embedded data from the deleterious effects of lossy compression.

In its simplest form, steganography in images is accomplished by replacing the least significant bits of the pixel bytes with the data to be embedded. Since images are frequently compressed for storage or transmission, it is desirable that a steganographic technique include some form of redundancy coding to counter the errors caused by lossy compression algorithms. Specifically, the Joint Photographic Expert Group (JPEG) compression algorithm, while producing only a small amount of visual distortion, introduces a relatively large number of errors in the bitmap data. These errors will effectively garble any non-coded steganographically embedded data.

This thesis shows that, although there are numerous protocols for embedding data within pixels, the limiting factor is always the number of bits modified in each pixel. A balance must be found between the amount of data embedded and the amount of acceptable distortion. This thesis also demonstrates that, despite errors caused by compression, information can be encoded into pixel data so that it is recoverable after JPEG processing, though not with perfect accuracy.

1996 THESIS ABSTRACTS

GEOLOCATION WORKBENCH

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This thesis defines software requirements for a geolocation workbench software environment. A geolocation workbench is a tool that studies the algorithms that provide the location of an active transmitter using techniques such as Time Difference of Arrival (TDOA) or Frequency Difference of Arrival (FDOA). The study would involve efficiency of calculation, accuracy of results and sensitivity to error.

The approach taken was the development of a rapid prototype of the Geolocation Workbench. The prototype implements the Geolocation Workbench system user interface and is evaluated by the customer, Professor Loomis of the Department of Electrical and Computer Engineering, Naval Postgraduate School, to refine the requirements. The requirements call for measuring TDOA, FDOA and emitter motion errors.

The results were as follows: After three prototype demonstrations and six one hour meetings a total of 50 screen panels were created with the desired functionality described in each panel. The functions included having the ability to enter text, display graphics, make file selections and edit data.

DIPHONE-BASED SPEECH RECOGNITION USING NEURAL NETWORKS

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Speaker-independent automatic speech recognition (ASR) is a problem of long-standing interest to the Department of Defense. Unfortunately, existing systems are still too limited in capability for many military purposes. Most large-vocabulary systems use phonemes (individual speech sounds, including vowels and consonants) as recognition units. This research explores the use of diphones (pairings of phonemes) as recognition units. Diphones are acoustically easier to recognize because coarticulation effects between the diphone's phonemes become recognition features, rather than confounding variables as in phoneme recognition. Also, diphones carry more information than phonemes, giving the lexical analyzer two chances to detect every phoneme in the word. Research results confirm these theoretical advantages. In testing with 4490 speech samples from 163 speakers, 70.2% of 157 test diphones were correctly identified by one trained neural network. In the same tests, the correct diphone was one of the top three outputs 89.0% of the time. During word recognition tests, the correct word was detected 85% of the time in continuous speech. Of those detections, the correct diphone was ranked first 41.6% of the time and among the top six 74% of the time. In addition, new methods of pitch-based frequency normalization and network feedback-based time alignment are introduced. Both of these techniques improved recognition accuracy on male and female speech samples from all eight dialect regions in the U.S. In one test set, frequency normalization reduced errors by 34%. Similarly, feedback-based time alignment reduced another network's test set errors from 32.8% to 11.0%.

1996 THESIS ABSTRACTS

TECHNOLOGY TRANSFER OF THE COMPUTER-AIDED PROTOTYPING SYSTEM (CAPS)

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The inability of the Department of Defense (DoD) to accurately and completely specify requirements for hard real-time software systems has resulted in poor productivity, schedule overruns, and software that is unmaintainable and unreliable. The Computer-Aided Prototyping System (CAPS) provides a capability to quickly develop functional prototypes to verify feasibility of system requirements early in the software development process. It was built to help program managers and software engineers rapidly construct software prototypes of proposed software systems. CAPS was developed by the Software Engineering Group at the Naval Postgraduate School (NPS) in Monterey, California.

This thesis investigates the transfer of technology of CAPS from NPS to DoD and the commercial industry. The effective transfer of technology requires user awareness of the technology and the ability to utilize the technology. Thus, a strategy is prepared for implementing the technology transfer of CAPS at NPS. To aid in this implementation, the quality and effectiveness of existing CAPS technical documentation is evaluated and recommendations for enhancement provided. Information dissemination materials are developed as part of this thesis which include three levels of CAPS briefings to potential sponsors, a home page, and a CD-ROM multimedia presentation. The implementation of this strategy will not only maximize the transfer of technology to the users, but also provide the optimum use of DoD software engineering resources available.

DESIGN AND ANALYSIS OF AN OBJECT-ORIENTED DATABASE OF ELECTRONIC WARFARE DATA

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Master of Science in Computer Science-May 1996**

**Advisors: David K. Hsiao, Department of Computer Science
C. Thomas Wu, Department of Computer Science**

The Electronic Warfare Integrated Reprogramming Database (EWIRDB) is the primary Department of Defense (DoD) approved source of electronic warfare (EW) data. Its utilization in the areas of battle planning and EW research enables our military forces to effectively exploit the electromagnetic spectrum and shape the outcome of battle. The EWIRDB, however, lacks a viable conceptual data model. EWIRDB data are represented in disjoint parametric tree models that are implementation-oriented; to the extent that the tree structures are used as conceptual modeling tools, their hierarchical form is too restrictive to adequately describe EW data semantics. Moreover, these structures address only technical parametric data. Associated administrative, reference, and comment data are excluded. In practice, the EWIRDB is described in terms of the coded and record-based format of its output media, not its conceptual model.

The primary goal of this thesis is the development of a semantically-improved conceptual design of EWIRDB data based on the object-oriented data model (OODM). The secondary goal of the thesis is the specification of a logical design, based on the new conceptual design, to provide the structure for a subsequent implementation of EWIRDB data on the Multimodel and Multilingual Database System (M²DBS) in the Laboratory for Database Systems Research at the Naval Postgraduate School.

The results of the work contained herein are: (1) an object-oriented conceptual design of EWIRDB data that supports the semantics of both the file format and tree structures, and (2) the specification of an object-oriented logical design for an M²DBS implementation of sample EWIRDB data.

1996 THESIS ABSTRACTS

INTERNETWORKING: THE INTEROPERABILITY OF COMMERCIAL MOBILE COMPUTERS WITH THE USMC DIGITAL AUTOMATED COMMUNICATIONS TERMINAL (DACT)

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Master of Science in Computer Science-September 1996

Advisor: Don Brutzman, Undersea Warfare Academic Group

Second Reader: Lou Stevens, Department of Computer Science

The United States Marine Corps has begun to develop a system called the Digital Automated Communications Terminal (DACT). The DACT system is based around a subnotebook-sized, tactical input/output battlefield situational awareness system and communications terminal. The problem is that DACT's excessive weight, size, cost and complexity might ultimately prevent its successful integration into the rapidly evolving Marine Corps style of maneuver warfare.

This thesis provides a study of palmtop-sized mobile computing platforms to include the Hewlett-Packard family of palmtops, as well as the emerging Microsoft® Pegasus mobile operating system. Furthermore, various messaging standards, protocols and commercial digital transmission channels are analyzed for their suitability to DACT requirements. Finally, a system prototype called the "Rapid Electronic Delivery of Messages over Asynchronous Networks" (REDMAN) is implemented to disseminate field orders under combat conditions. REDMAN speeds the flow of accurate information to all levels of command within a Marine infantry battalion using a commercial palmtop platform. This commercial palmtop is 3-7 times lighter and 20-30 times less expensive than DACT. Wireless networked palmtop computing will completely change the scope of Marine warfighting. This thesis provides a proof of concept system that demonstrates such fundamental change is feasible today.

IMPLEMENTATION AND EFFICIENCY OF STEGANOGRAPHIC TECHNIQUES IN BITMAPPED IMAGES AND EMBEDDED DATA SURVIVABILITY AGAINST LOSSY COMPRESSION SCHEMES

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and

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Harold Fredricksen, Department of Mathematics

The term steganography is descriptive of techniques used to covertly communicate by embedding a secret message within an overt message. Such techniques can be used to hide data within digital images with little or no visible change in the perceived appearance of the image and can be exploited to covertly export sensitive information. This thesis explores the data capacity of bitmapped image files and the feasibility of devising a coding technique which can protect embedded data from the deleterious effects of lossy compression.

In its simplest form, steganography in images is accomplished by replacing the least significant bits of the pixel bytes with the data to be embedded. Since images are frequently compressed for storage or transmission, it is desirable that a steganographic technique include some form of redundancy coding to counter the errors caused by lossy compression algorithms. Specifically, the Joint Photographic Expert Group (JPEG) compression algorithm, while producing only a small amount of visual distortion, introduces a relatively large number of errors in the bitmap data. These errors will effectively garble any non-coded steganographically embedded data.

This thesis shows that, although there are numerous protocols for embedding data within pixels, the limiting factor is always the number of bits modified in each pixel. A balance must be found between the amount of data embedded and the amount of acceptable distortion. This thesis also demonstrates that, despite errors caused by compression, information can be encoded into pixel data so that it is recoverable after JPEG processing, though not with perfect accuracy.

1996 THESIS ABSTRACTS

PRECISION CONTROL AND MANEUVERING OF THE PHOENIX AUTONOMOUS UNDERWATER VEHICLE (AUV) FOR ENTERING A RECOVERY TUBE

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Because of range limitations imposed by speed and power supplies, covert launch and recovery of Autonomous Underwater Vehicles (AUVs) near the operating area will be required for their use in many military applications. This thesis documents the implementation of precision control and planning facilities on the *Phoenix* AUV that will be required to support recovery in a small tube and provides a preliminary study of issues involved with AUV recovery by submarines.

Implementation involves the development of low-level behaviors for sonar and vehicle control, mid-level tactics for recovery planning, and a mission-planning system for translating high-level goals into an executable mission. Sonar behaviors consist of modes for locating and tracking objects, while vehicle control behaviors include the ability to drive to and maintain a position relative to a tracked object. Finally, a mission-planning system allowing graphical specification of mission objectives and recovery parameters is implemented.

Results of underwater virtual world and in-water testing show that precise AUV control based on sonar data can be implemented to an accuracy of less than six inches and that this degree of precision is sufficient for use by higher-level tactics to plan and control recovery. Additionally, the mission-planning expert system has been shown to reduce mission planning time by approximately two thirds and results in missions with fewer logical and programming errors than manually generated missions.

NPSNET VEHICLE DATABASE: AN OBJECT-ORIENTED DATABASE IN A REAL-TIME VEHICLE SIMULATION

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Masters of Science in Computer Science-June 1996
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David R. Pratt, Department of Computer Science

The Naval Postgraduate School has actively explored the design and implementation of NPSNET, a real-time three-dimensional simulator on low-cost, readily accessible workstations. NPSNET involves a tremendous amount of interaction between vehicle, terrain, obstacle and ordnance objects in a dynamic simulation system. There exists a need for an organized, efficient storage structure that allows real-time retrieval of objects and their interactive relationships.

This work concentrates on selection and design of a vehicle database model to maximize storage and real-time retrieval of data for the NPSNET visual simulator. The results of this effort can be applied to the overall system, NPSNET, in a distributed database management system.

IMPLEMENTING VOICE RECOGNITION AND NATURAL LANGUAGE PROCESSING IN THE NPSNET NETWORKED VIRTUAL ENVIRONMENT

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John Falby, Department of Computer Science

Interfaces to military Virtual Reality (VR) systems, such as NPSNET IV.9, have been limited mainly to keyboard, mouse, and joystick devices. This presents two major problems; remembering how to access all the functionality of the

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system, and using the interface when the user is otherwise physically constrained. This can occur during the use of body-position tracking devices and Heads-Up-Displays (HUD). Voice recognition and Natural Language Processing (NLP) were used as a solution to both problems.

The approach taken was to develop a networked Spoken Language System (SLS) using a Commercial-Off-The-Shelf (COTS) voice recognition and NLP system. The Nuance Speech Recognition System from Nuance Communications was chosen after analyzing the special requirements of NPSNET. Implementing the SLS occurred in four phases. First, vocabularies and grammars were developed to simulate the 108 keyboard commands, focusing on flexibility and decreased response latency. Second, new C++ classes were written to ease reuse of the Nuance API's. Third, a control panel was written to manage the voice processing, and fourth, the code was integrated into NPSNET.

As a result of this effort, a new voice-enabled interface exists for NPSNET. In addition, C++ classes exist to ease future use of the Nuance API in other software systems. All of the 108 keyboard commands are executable through voice control with a 83.8% sentence understanding rate in a noisy background environment.

THE ACTIVATION AND TESTING OF THE NETWORK CODASYL-DML INTERFACE OF THE M²DBMS USING THE EWIR DATABASE

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and**

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The Electronic Warfare Integrated Reprogramming Database (EWIRDB) is the primary Department of Defense source for technical parametric performance data on noncommunications emitters. A problem of the EWIRDB is that the data are represented in disjoint parametric tree models that are implementation oriented. The parametric tree with its deceptive hierarchical structure, provides a poor modeling construct that obscures the intended semantics and representation of the data, thus making the database difficult to use and understand from a users perspective. The problem addressed by this thesis is to determine if the network model and the network interface of the Multi-Lingual, Multi-Model Database Management System (M²DBMS) in the Laboratory for Database Systems Research at the Naval Postgraduate School is capable of supporting a representative subset of the EWIRDB.

The primary goal of this thesis is to implement a representative portion of the EWIR database on the network interface of the M²DBMS. In order to accomplish this goal, the following issues must be addressed: First, the network interface must be activated and returned to its original operational state; second, the network interface must be tested to determine its capabilities and limitations; and last, the design and specification of a network EWIR data model must be completed prior to its implementation.

We successfully reactivated the network interface to its original operational state. However, testing revealed significant limitations of the network interface. Due to these limitations, only the data definition portion of our proposed design was fully implemented.

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FORMAL SPECIFICATION, VERIFICATION, AND ANALYSIS OF THE RELIABLE MULTICAST TRANSPORT PROTOCOL

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This thesis explores the feasibility and reliability of a Reliable Multicast Transport Protocol (RMTP) under development at AT&T Bell Laboratories. A formal specification and verification was conducted using the *systems of communicating machines* model to determine if the specification of the protocol is free from deadlocks, livelocks, and unspecified receptions. This model was programmed using the ADA programming language. An analysis was done using these programs as input to programs that perform reachability analysis on the model of the protocol. Results of the analysis indicate that the RMTP protocol is free from deadlocks and livelocks with a few exceptions. Suggestions are provided to improve the specification of the protocol. In addition to the research on the RMTP protocol, greater knowledge was acquired in the area of modeling communication channels and networks.

INTERNETWORKING: AUTOMATED LOCAL AND GLOBAL NETWORK MONITORING

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Master of Science in Computer Science-September 1996

Advisor: Don Brutzman, Undersea Warfare Academic Group

Second Reader: Lou Stevens, Department of Computer Science

Commercial applications for network monitoring are expensive and therefore not widely available to the majority of network users. Public domain network monitoring software is generally effective in the hands of an expert but difficult to use by the common user because of its command line driven interface. It is a basic tenet of this thesis that network performance and security can be improved if all network users had easy-to-use network monitoring tools available and were encouraged to use them frequently. In this thesis, *ping*, *traceroute*, and *nslookup* were integrated with the familiar user-friendly interface provided by the World Wide Web (WWW) and HyperText Markup Language (HTML) in both automated and interactive versions. These easy to use monitoring tools were evaluated in several working environments at the Naval Postgraduate School and the Monterey Bay Area Network. *ping*, *traceroute* and *nslookup* can now be performed in one-sixth of the time previously required for an expert user. Current network status is now readily available and can be validated at any time through the use of the applications developed in this thesis.

REACTIVATION OF THE RELATIONAL INTERFACE IN M²DBMS AND IMPLEMENTATION OF THE EWIR DATABASE

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The primary Department of Defense source for technical parametric performance data on non-communications emitters is the Electronic Warfare Reprogramming Database (EWIRDB). Data representation in the EWIRDB is via disjointed parametric tree models which are implementation oriented. These parametric trees obscure the intended seman-

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tics and representation of the data, making the database difficult to use and understand. The problem addressed by this thesis is to determine if the relational model and the relational interface of the Multimodel and Multilingual Database System (M²DBMS) in the Laboratory for Database Systems Research at the Naval Postgraduate School is capable of supporting a representative subset of the EWIRDB.

We implemented a representative portion of the EWIR database on the relational interface of the M²DBMS. In order to accomplish this the relational interface was reactivated and returned to its original operational state and fully tested to determine its capabilities. In addition, the schema and an instance of a relational EWIR data model must be developed for implementation.

The relational interface was successfully returned to its original operational state. Significant limitations in the interface's ability to process queries were discovered, however, in that the system can not query schema of greater than four relations.

INTERNETWORKING: IMPLEMENTATION OF MULTICASTING AND MBONE OVER FRAME RELAY NETWORKS

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Master of Science in Computer Science-September 1996

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Michael Zyda, Department of Computer Science**

The major problems addressed by this thesis research are how to implement multicast over the Monterey BayNet to enable live audio/video for distance learning, how to safely integrate regional Frame Relay multicast with the global MBone, and how to monitor multicast connectivity over the Monterey BayNet.

To implement multicast and MBone over the Monterey BayNet without using dedicated multicast servers, we enabled Protocol Independent Multicast (PIM) protocol on already-installed Frame-Relay-capable routers. By implementing multicast over Monterey BayNet, we show that the current MBone software provides the same performance that it provides on regular Internet connections even on low-speed (128Kbps) Frame Relay network connections and low-cost personal computers. In order to control the scope of the regional multicast and to safely integrate regional Frame Relay multicast with the global MBone, we used administratively controlled multicast group address (224.0.1.20) in addition to the use of time-to-live (TTL) control mechanism. This eliminates global duplication of multicast packet delivery.

Public-domain multicast monitoring tools are used to monitor the multicast connectivity through internetworks. Since these tools are available only to UNIX-based platforms, they cannot be used by the regional sites that mostly have Windows and Macintosh platforms. We developed Web-accessible multicast monitoring pages in order to meet the multicast monitoring needs of the regional sites. Participating sites are now able to monitor regional multicast connectivity by accessing these pages, which permits remote problem diagnosis. That was previously impossible. Finally we synopsise firewall requirements for secure and effective use of multicast.

1996 THESIS ABSTRACTS

PORTING HIGH QUALITY GRAPHICS SIMULATIONS TO A LOW-COST COMPUTER ARCHITECTURE

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Master of Science in Computer Science-September 1996

and

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John S. Falby, Department of Computer Science

Two disadvantages of using Silicon Graphics®, Inc. (SGI) computers and SGI's IRIS }3 Performer™ application programming interface (API) in NPSNET are the current inability to run the graphic simulations on more popular environments, such as personal computer (PC) operating systems (OSs), and the increased expense associated with the alternative of choosing graphics specific hardware over lower cost PCs. Work detailed in this thesis addresses these problems by porting graphics code from NPSNET to relatively inexpensive PC hardware running the Microsoft® Windows NT™ OS.

Two independent approaches were taken. The first created a library of graphics calls which simulate the syntax and functionality of Performer calls, but which have been redefined in terms of the Gemini Technology Corporation's OpenGVS™ API, which is capable of running on the NT platform. The second proposed and implemented a prototype graphics display manager coded using only OpenGVS, rather than Performer, for a proposed platform-independent redesign of NPSNET.

As a result of this effort, the goal of porting IRIS Performer graphics simulations to the PC has been accomplished, and a new architecture for NPSNET display managers has been validated.

APPLICATION OF INERTIAL SENSORS AND FLUX-GATE MAGNETOMETER TO REAL-TIME HUMAN BODY MOTION CAPTURE

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Master of Science in Computer Science-September 1996

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Michael Zyda, Department of Computer Science

Second Reader: Russ Whalen, Department of Computer Science

Human body tracking for synthetic environment interface has become a significant human-computer interface challenge. There are several different types of motion capture systems currently available. Inherent problems, most resulting from the use of artificially-generated source signals, plague these systems. A proposed motion capture system is being developed at the Naval Postgraduate School which utilizes a combination of inertial sensors to overcome these difficulties. However, the current design exhibits azimuth drift errors resulting from the use of inertial sensors.

This thesis proposes a new method of compensating for azimuth drift using a three-axis fluxgate magnetometer. The fluxgate magnetometer is capable of azimuth drift compensation since its sensitive axis is not collinear with the local vertical. This thesis includes a program for simulating the operation of a fluxgate magnetometer in C++. The included C++ code simulates a fluxgate magnetometer and provides an estimate of azimuth based on the magnetometer's output which is typically within five degrees of the actual azimuth. Real magnetometer data for testing and verification was accomplished by bench testing a real fluxgate magnetometer.

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A NATIONAL IMAGERY SYSTEMS SECURITY POLICY

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Advisor: Cynthia E. Irvine, Department of Computer Science

The Central Imagery Office (CIO) has no Information Systems Security Policy (ISSP). Therefore, this thesis: 1) outlines the CIO's mission, 2) identifies the necessary elements of an ISSP, 3) summarizes the accreditation process, 4) proposes a new network view—the Feudal view, 5) reviews higher level ISSP guidance, then 6) proposes a National ISSP to guide the CIO in its role of accrediting systems and networks under its purview in a multi-accreditor environment. The policy specifies the following minimum security requirements: confidentiality, integrity, availability, authenticity, and accountability; for both individual systems and networks. The thesis promotes a risk management approach by indicating that lesser constraints can be invoked for systems that are not considered “critical sources” for imagery. The Feudal network view would permit systems to exchange sensitive and classified data over open/public networks provided that they: 1) incorporate an NSA approved trusted front end, 2) communicate via NSA approved cryptographic mechanisms, and 3) follow a defined set of information transfer rules. One such set of rules are presented, and are intended to both: enforce the DoD access policy, and preclude the “cascade” and “propagation of risk” vulnerabilities discussed in the National Computer Security Center's *Trusted Network Interpretation*.

INFORMATION SYSTEMS SECURITY REQUIREMENTS FOR THE ENGINEERING 2000 INITIATIVE OF THE TOMAHAWK ENGINEERING COMMUNITY

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and

Nina R. Kenmore-Lieutenant, United States Navy

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Master of Science in Information Technology Management-March 1996

Advisors: Magdi N. Kamel, Department of Systems Management

Roger Stemp, Department of Computer Science

The Tomahawk Engineering community's *Engineering 2000 Initiative*, sponsored by the Cruise Weapons Department at the Port Hueneme Division of the Naval Surface Warfare Center (NSWC-PHD), integrates engineering, logistics and management tools into a single desktop computer. This integration creates problems in providing suitable Information Systems Security (ISS). This thesis addresses ISS and suggests areas that require management attention. The thesis includes a discussion of ISS issues, policies, and initiatives, a development of the ISS Management Model and a methodology for its use; an application of the Model methodology in the assessment of the *Baseline ISS Management State*; and an application of the Model's methodology in the development of the *Target ISS Management State*. The difference between the *Target ISS Management State* and *Baseline ISS Management State* produces a list of ISS recommendations to bridge the gap between the states. Some of these recommendations include: restructuring NSWC-PHD's ISS organization, increasing user awareness, centralizing user accountability to the ISS staff, and increasing management commitment to NSWC-PHD's ISS policies.

1996 THESIS ABSTRACTS

THE DEVELOPMENT OF A RELATIONAL DATABASE TO SUPPORT THE FLIGHT HOUR PROGRAM OF COMMANDER, NAVAL AIR FORCES PACIFIC

Mark J. Gonzalez-Commander, United States Navy

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Master of Science in Computer Science-September 1996

and

Mitch R Hayes-Lieutenant, United States Navy

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Master of Science in Computer Science-June 1996

Advisors: C. Thomas Wu, Department of Computer Science

John Falby, Department of Computer Science

The Air Forces Pacific Financial Analysis Tool (AFAST) has been described by senior leadership within the Air Forces Pacific (AIRPAC) staff as inaccurate, marginally satisfactory and too small in scope to produce output in a relevant and timely manner. Moreover, improvements to the current database are time consuming and cost prohibitive; the absence of adequate design documentation prohibits major modification of the database without significant investment of the limited resources possessed by AIRPAC.

The primary goal of this thesis is the development of an improved conceptual design of the AFAST database based on the enhanced entity-relationship model concepts. The secondary goals of the thesis are the specification of the logical design of the improved database, and the implementation of AFAST II, a prototype application of the redesigned database.

The results of this thesis are: (1) an enhanced entity-relationship model that fully meets the design goals of Naval Air Forces Pacific, (2) the specification of the logical design for the implementation of the redesigned database, and (3) the development of a prototype application validating the conceptual and logical designs.

ENHANCEMENTS FOR THE CAPS PROTOTYPING SYSTEM DESCRIPTION LANGUAGE SYNTAX-DIRECTED EDITOR

Scott Robert Grosenheider-Captain, United States Marine Corps

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Master of Science in Computer Science-March 1996

Advisor: Man-Tak Shing, Department of Computer Science

CAPS (Computer-Aided Prototyping System) is an integrated set of software tools that generate source programs directly from real-time requirements. CAPS users can specify the requirements of prototypes as augmented computational graphs using the graphics/text editor. The problem with the current version of CAPS is that most of the feasibility checks for the prototypes are currently enforced by the translator and the scheduler. Such an approach requires the engineers to go through the "edit, save file, then translate and schedule" cycle in order to find out if the control and timing constraints can be satisfied.

The prototyping process can be made much more efficient and user-friendly if these checks are enforced by the CAPS PSDL (Prototype System Description Language) SDE (syntax-directed editor), where users can detect and receive warnings as they enter the design. This thesis focuses on the properties that must exist between processes and their inter-connected data flows in order for a prototype to be correct. It further modifies the PSDL SDE so that parts of the prototype are captured, combined, and manipulated in a way that provides the semantic information needed to determine if these properties have been violated.

The new editor has been applied to several prototype examples. The results showed that, by catching errors during the editing phase, the user saves time, is better able to stay focused on the design, and is subsequently more productive.

1996 THESIS ABSTRACTS

AN ANALYSIS OF FUTURE CAPACITY REQUIREMENTS FOR THE U.S. ARMY'S TACTICAL PACKET NETWORK

Paul J. Haffey-Major, United States Army

B.S., Fordham University, 1994

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Advisor: Gilbert M. Lundy, Department of Computer Science

This thesis examines the U.S. Army's infrastructure for data communication in a tactical environment, in light of anticipated requirements. The first part of the study covers the nature of this problem; it is a technology forecast for an infrastructure project. This is used as a foundation for the discussion of the Army's approach to determining its future acquisition plan in Chapter III. Chapter IV considers the future use of the network in terms of the types of application programs that are likely to run over the network. Chapter V then considers the communications capacity that will be required simply to establish and operate the network itself. The conclusions are summarized in Chapter VI.

The conclusion of this study is that the optimum future network capacity will greatly exceed the level that would be predicted by extrapolating from currently identified uses. This future level of demand will need to be supported by the network infrastructure, which requires a long lead time and large capital investment to put in place. Because future demand for digital communications will grow so rapidly, an aggressive approach to determining the future network capacity requirement is recommended. In the next ten year period, any capacity available will likely be utilized rapidly resulting in desirable operational and cost saving benefits. Therefore, future capacity should be determined to a large degree by the maximum that it is technically and economically feasible to provide.

AN ANALYSIS OF THE ARMY'S TACTICAL PACKET NETWORK

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Advisors: Gilbert M. Lundy, Department of Computer Science

Orin E. Marvel, Command, Control, and Communications Academic Group

This thesis represents an analysis of the U.S. Army's Tactical Communications System with particular emphasis on the Tactical Packet Network (TPN). It is a study of the Army's TPN and the proposed upgrade solutions. The U.S. Army awarded GTE a contract to replace the TPN Exterior Gateway Protocol with the Border Gateway Protocol. Additionally, the U.S. Army intends to upgrade the bandwidth of the Small Extension Node Switch and the Node Center Switch. The goal of both upgrades is to enhance the TPN.

One cannot look at TPN without looking at the overall infrastructure or the Army Tactical Command and Control System (ATCCS). Even this view is shortsighted. The ATCCS continues to evolve to meet the information requirements of the warfighter. Thus, a fair study must include our current capabilities and our future intentions for C4I. This thesis analyzes both.

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THE DEVELOPMENT OF A RELATIONAL DATABASE TO SUPPORT THE FLIGHT HOUR PROGRAM OF COMMANDER, NAVAL AIR FORCES PACIFIC

Mitch R Hayes-Lieutenant, United States Navy

B.S., Seattle University, 1988

Master of Science in Computer Science-June 1996

and

Mark J. Gonzalez-Commander, United States Navy

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Master of Science in Computer Science-September 1996

Advisors: C. Thomas Wu, Department of Computer Science

John Falby, Department of Computer Science

The Air Forces Pacific Financial Analysis Tool (AFAST) has been described by senior leadership within the Air Forces Pacific (AIRPAC) staff as inaccurate, marginally satisfactory and too small in scope to produce output in a relevant and timely manner. Moreover, improvements to the current database are time consuming and cost prohibitive; the absence of adequate design documentation prohibits major modification of the database without significant investment of the limited resources possessed by AIRPAC.

The primary goal of this thesis is the development of an improved conceptual design of the AFAST database based on the enhanced entity-relationship model concepts. The secondary goals of the thesis are the specification of the logical design of the improved database, and the implementation of AFAST II, a prototype application of the redesigned database.

The results of this thesis are: (1) an enhanced entity-relationship model that fully meets the design goals of Naval Air Forces Pacific, (2) the specification of the logical design for the implementation of the redesigned database, and (3) the development of a prototype application validating the conceptual and logical designs.

RADIANT MERCURY: AN ASSESSMENT OF THE ISSUES

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The Department of Defense (DoD) has a need to disseminate classified information in a controlled manner. Often classified information must be filtered and/or sanitized prior to its release to particular entities. Sensitive information can be particularly vulnerable to human error in release decisions when a high volume of information is involved. Radiant Mercury (RM) is a system designed to alleviate some of the problems associated with such scenarios. By discussing the automated dissemination of classified information with appropriate DoD agencies as well as obtaining briefings from the developers of RM, an analysis of the system was possible. Topics discussed in this thesis include: 1) the adequacy of assurance provided by a Class B1 evaluated system, 2) the intricacy and content/context sensitivity of the RM rules, 3) the near term obsolescence of the RM evaluated hardware platform, 4) the impact of rules modification on system accreditation, and 5) the need for training of RM users. Overall, Radiant Mercury provides an automated system for filtering and disseminating information that may be useful where high message throughput is needed.

1996 THESIS ABSTRACTS

USER INTERFACE AND DATABASE DESIGN FOR SOFTWARE DATABASE OF THE COMPUTER-AIDED PROTOTYPING SYSTEM (CAPS)

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CAPS (Computer-Aided Prototyping System) is an integrated set of software tools that generate prototypes directly from real-time requirements. The success of CAPS depends on being able to generate the prototype quickly so that it can be evaluated, leading to the construction of a program built on true requirements thereby resulting in a better software product. The key to developing prototypes quickly is having a significant software base to choose reusable components from. The problem with the current version of CAPS is that there exists no software base storage facility.

This thesis utilizes the ONTOS database to build the object oriented conceptual design for the data object repository and uses TAE to create the graphical user interface to access the repository. It further explores various searching techniques to determine the best possible implementation of the repository search engine.

The results of this thesis are a conceptual design that can be used to implement the software base and an interface which provides a fluid, intuitive, interactive environment in which the user will be able to manipulate the database when actually built. It further identifies the multi-level filtering technique as the best candidate for searching the database, because of its high recall, high precision, and reduced search time.

A MODEL AND DECISION SUPPORT MECHANISM FOR SOFTWARE REQUIREMENTS ENGINEERING

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The early portion of the software prototyping process is missing automatic support for many important activities that help the software manager and the design team members firm up requirements and control the system design and evolution to satisfy the customers' real needs. This dissertation introduces a formal model for requirements analysis and evolution and a decision support mechanism based on that model. Both the model and the decision support mechanism provide the missing support identified above. Within the framework of this model the support provided spans the whole life cycle of the software development process. The model is used to capture user reactions to the demonstrated behavior of a prototype and map these reactions into the model objects to be used in synthesizing a set of open issues to be resolved. The issues are resolved by examining and modifying requirements if necessary, and then propagating the change consequences down into the affected parts of system specification and implementations in a consistent and controlled manner.

This process is performed through a set of analysis and design activities controlled by the manager and aided by the decision support mechanism based on the formal model. This approach also provides support for maintaining design history and its rationale that can be used for implementing new needs or performing comparative studies to choose among alternatives.

A formalism is also developed that supports customers in choosing among available alternatives to requirements that satisfy their goals and meet other constraints. An improved decision support method based on this formalism supports individuals that represent different customer view points to reach a final decision that represents the combined view of the group.

A database is an important component of any decision support mechanism. This work also provides a conceptual design of an engineering database capable of representing and managing the process knowledge. This knowledge includes all information related to a software prototype design. The management of this information includes storing, retrieving, viewing, and controlling the design knowledge. The design of this engineering database is based on the

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object oriented paradigm. This paradigm provides the representation power to easily map our model objects and their relationships efficiently and naturally.

A new implementation model has also been developed that provides smooth and safe communication between the implementation language and the database manipulation language. The new implementation technique based on that model also allows the implementation language to directly access the database facilities. This access is done without going through intermediate layers of codes that must be implemented in another language. This is not possible without the new technique.

RE-ENGINEERING OF THE COMPUTER-AIDED PROTOTYPING SYSTEM FOR PORTABILITY

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The Computer-Aided Prototyping System (CAPS) Release 1 currently runs only on SPARC workstations running SunOS version 4.1.3. This limits the usefulness of CAPS, particularly since Sun has announced it has no plans to continue support for SunOS version 4.x. A solution to this problem is to increase the portability of CAPS by first porting CAPS to the Solaris 2.5 operating system.

Towards this end, this thesis discusses and evaluates the underlying system software and software tools necessary to build and run CAPS within the Solaris 2.5 operating environment for SPARC workstations.

As a result of this effort, a version of CAPS has been created that runs on a SPARC workstations using the Solaris 2.5 operating system. Furthermore, the research has identified the necessary software tools and potential problem areas for determining the feasibility of porting CAPS to other platforms. Versions of X Windows, Motif, Synthesizer Generator, Eli, TAE Plus, and the VADSelf Ada compiler are required. Since TAE Plus only supports the SunAda (VADS) compiler, use of a different Ada compiler will require either porting the TAE Ada bindings or using an alternative to TAE Plus. Additionally, an explicit installation of Motif is required to provide all the libraries needed to produce static builds of the CAPS components.

GEOLOCATION WORKBENCH DEVELOPMENT SYSTEM

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Herschel H. Loomis, Jr., Department of Electrical and Computer Engineering

This thesis provides a common signal abstraction for the geolocation workbench. The geolocation workbench is a software tool used to develop, modify and test geolocation algorithms. Electronic signals come from a variety of sources, in many different formats and with different descriptive parameters. This has been a hindrance to the development of geolocation and signal processing algorithms.

The approach taken was to examine existing signal formats and synthesize a common format to be used within the geolocation workbench. Utilizing object-oriented techniques a signal class hierarchy was developed consisting of a SIGNAL class and sub-classes of Pulse Descriptor Word and Digital IF signals.

The results of this thesis are a common abstraction for representing signals, and high level design for the Signal Management functions of the Workbench. This abstraction provides access for a broad class of algorithms to access signal data sets. The storage of signal sets in both their raw format and the converted format facilitates the development of geolocation algorithms as well as filtering and signal processing algorithms.

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INFORMATION SYSTEMS SECURITY REQUIREMENTS FOR THE ENGINEERING 2000 INITIATIVE OF THE TOMAHAWK ENGINEERING COMMUNITY

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and

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The Tomahawk Engineering community's *Engineering 2000 Initiative*, sponsored by the Cruise Weapons Department at the Port Hueneme Division of the Naval Surface Warfare Center (NSWC-PHD), integrates engineering, logistics and management tools into a single desktop computer. This integration creates problems in providing suitable Information Systems Security (ISS). This thesis addresses ISS and suggests areas that require management attention. The thesis includes a discussion of ISS issues, policies, and initiatives, a development of the ISS Management Model and a methodology for its use; an application of the Model methodology in the assessment of the *Baseline ISS Management State*; and an application of the Model's methodology in the development of the *Target ISS Management State*. The difference between the *Target ISS Management State* and *Baseline ISS Management State* produces a list of ISS recommendations to bridge the gap between the states. Some of these recommendations include: restructuring NSWC-PHD's ISS organization, increasing user awareness, centralizing user accountability to the ISS staff, and increasing management commitment to NSWC-PHD's ISS policies.

PROMOTING DISTANCE EDUCATION AT NAVAL POSTGRADUATE SCHOOL (NPS)

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This thesis defines and supports five recommendations for Naval Postgraduate School (NPS) to promote its distance education program. The research and interviews in this study were primarily done to find the current barriers and requirements needed to conduct distance education on a larger scale. The research began with defining the Department Chairmen's concerns with distance education at NPS. Each recommendation, developed from the concerns, is supported by interviews with Department Chairmen, Educators, and Administrators, as well as literary findings. Implementation requirements and benefits to both the DoN and NPS are also provided for each recommendation.

The first recommendation this thesis supports is for NPS to develop a mission and vision statement for distance education. The second is to establish a NPS Distance Education Support Center to centralize campus efforts in distance education. The third recommendation is to institute a NPS Distance Education Marketing Plan to find potential customers and increase distance education interest on campus. The fourth recommendation is for NPS to immediately determine the cost for distance education in order to request additional funding from DoN. Finally, the study recommends NPS begin a pilot program as a model for future distance education for active duty officers in the fleet. The proposed pilot program presented in this study is with HSL-41, a LAMPS Mark-III Squadron. With these recommendations, this thesis looks to make NPS the "Navy's Distance Education University." This study concludes with a timeline for implementing these recommendations.

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THE DESIGN AND IMPLEMENTATION OF A COMPILER FOR THE OBJECT-ORIENTED DATA MANIPULATION LANGUAGE

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Object-oriented relationships, such as inheritance and covering can not be readily incorporated in classic data models. This thesis addresses this problem by the design and implementation of an object-oriented data model (O-ODM), that incorporates the object-oriented paradigm.

A Multimodel and Multilingual Database System called M²DBS has been developed at the Naval Postgraduate School. This system incorporates the classic database data models along with a recently developed object-oriented data model (O-ODM). The problem addressed by this work is to design a new object-oriented data manipulation language (O-ODML) for the O-ODM. The approach is to develop and construct an O-ODML Compiler. Then assimilate the compiler with the Kernel Mapping System (KMS) of the M²DBS.

The result of this thesis is a compiler for the O-ODML of the O-ODM. This O-ODML compiler takes an O-ODM query converts it into a low level intermediate language before translating it into a format that the Real Time Monitor can execute on the M²DBS.

THE OBJECT-ORIENTED DATABASE AND PROCESSING OF ELECTRONIC WARFARE DATA

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Thomas D. McKenna-Lieutenant Commander, United States Navy

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The Electronic Warfare Integrated Reprogramming (EWIR) database is the primary Department of Defense source for technical parametric performance data on noncommunications emitters. It has been identified by the National Air Intelligence Center as difficult to use in its current hierarchical database form. There are two problems addressed by this thesis. First, is an object-oriented EWIR database a superior method for managing complex electronic warfare data collections? Second, is the prototype Object-Oriented Interface (O-OI) developed at the Laboratory for Database System Research in the Naval Postgraduate School capable of supporting a complex object-oriented database such as EWIR?

To answer these questions, a *subset* of the EWIR Object-Oriented Specification developed in a separate thesis is implemented on the O-OI. Using the O-OI Data Definition Language, the object-oriented EWIR database schema and its associated record data are stipulated and loaded to create the live database. Using the O-OI Data Manipulation Language, nine EWIR transactions are elaborated and executed.

The first result of this thesis is the O-OI performs as specified, but requires additional data manipulation and logical control functions to handle complex databases. The minimum additional functions include *Insert*, *Delete*, and *If-then-else*. The inheritance feature also requires a generalization-to-specialization data retrieval capability. The second result of this thesis is the straightforward data manipulation capability of the object-oriented version of the EWIR database.

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The object-oriented specification more accurately captures data relationships. The inheritance, path, and object comparison features streamline the linkage of related data, thus simplifying ad hoc query construction.

**MISSION PLANNING AND MISSION CONTROL SOFTWARE
FOR THE PHOENIX AUTONOMOUS UNDERWATER VEHICLE (AUV):
IMPLEMENTATION AND EXPERIMENTAL STUDY**

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Robert B. McGhee, Department of Computer Science

The Naval Postgraduate School Autonomous Underwater Vehicle (AUV), Phoenix, has a well developed lower level architecture (Execution level) while the upper, Strategic and especially the Tactical, levels need refinement. To be useful in the fleet an easier means of creating mission code for the Strategic level is required. A software architecture needed to be implemented at the Tactical level on-board Phoenix which can accommodate multi-processes, multi-languages, multi-processors and control hard real-time constraints existing at the Execution level. Phoenix also did not have a path replanning capability prior to this thesis.

The approach taken is to provide Phoenix a user-friendly interface for the autogeneration of human-readable mission code and the creation and implementation of a Tactical level control architecture on-board Phoenix to include path replanning. The approach utilizes Rational Behavior Model (RBM) architectural design principles. This thesis focuses on the Officer of the Deck and replanning at the Tactical level, and refinement of the Captain at the Strategic level. While further testing is necessary, Phoenix is now capable of behaving as a truly autonomous vehicle.

Results of this thesis show that nontechnical personnel can generate Prolog code to perform missions on-board Phoenix. Path replanning and obstacle avoidance software are also implemented. Most important this thesis demonstrates successful operation of all three levels of the RBM architecture on-board Phoenix.

AUTONOMOUS CONTROL OF UNDERWATER VEHICLES AND LOCAL AREA MANEUVERING

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Doctor of Philosophy in Mechanical Engineering-September 1996

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Robert B. McGhee, Department of Computer Science

Fotis A. Papoulias, Department of Mechanical Engineering

Louis V. Schmidt, Department of Aeronautics and Astronautics

The major thrust of this work is the development and demonstration of new capabilities for the use of small autonomous vehicles in mine countermeasure applications. Key to the new capabilities lies in an open architecture tri-level software structure for hybrid control, of which this work is the first validated implementation. The two upper levels run asynchronously in computing logical operations based on numerical decision making, while the lowest, the Execution Level, runs synchronously to maintain stability of vehicle motion. The top (Strategic) Level of control uses Prolog as a rule based language for the specification of the discrete event system (DES) aspects of the mission. Multiple servo controllers are coordinated by the middle (Tactical) Level software in performing the mission, while the Execution Level controllers guarantee robust motion stability through multiple sliding modes.

This hardware/software arrangement provides the ability to operate a hybrid (mixed discrete state/continuous state) controller for semi-autonomous and autonomous vehicles in which the missions imply multiple task robot behavior. This work has defined and developed a set of vehicle "primitives", that are a set of stable modular control functions unique to a given vehicle's capabilities. It is demonstrated how these can easily be combined using rules to specify as

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simple, or as complex, a mission as desired. Completion of a mission is guaranteed through a "complete plan" including time traps and error recovery procedures. Experimental results are given illustrating the performance attained.

A particular case of the technique developed has resulted in a method to navigate an AUV in a local area (around a mine-like object) using a profiling sonar sensor for position information derived from underwater feature detection. Since sonar image feature extraction is necessarily time consuming, a dynamic model of the vehicle response is used for control between position updates. A structured formulation of this control/navigation method is presented followed by results from in water implementation using the NPS Phoenix vehicle and the tri-level software structure described above.

CONTROLLED ACCESS PROTECTION IN THE TELESRIPT™ PROGRAMMING LANGUAGE

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Second Reader: Louis D. Stevens, Department of Computer Science

Research on the ability of the Telescript™ language and execution mechanism to enforce controlled access protection on mobile agents moving in and across distributed computer networks has not been published. Nor has General Magic, the creator of the language, conducted security testing on their product.

This thesis investigates whether the mobile agents and execution mechanism proposed by General Magic in its Telescript™ language meet the Class C2 Controlled Access Protection criteria as promulgated in the Department of Defense Trusted Computer System Evaluation Criteria (TCSEC). This was done by conducting an analysis of the documentation provided by General Magic in their Telescript™ Development Kit (TDK) and Active Web Tools™ (AWT).

The results of this thesis show that the mobile agents and execution mechanism of the Telescript™ language do not meet the criteria for TCSEC Class C2 Controlled Access Protection. In particular, the criteria for object reuse, system architecture, system integrity, security testing and security documentation are not met. However, discretionary access control (DAC) can be enforced using a user-defined security policy and the requirements for identification and authentication (I&A) and audit are satisfied.

ENSURING A C2 LEVEL OF TRUST AND INTEROPERABILITY IN A NETWORKED WINDOWS NT ENVIRONMENT

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With the progression of computer systems to local and wide area networks, the scope of computer security has increased dramatically over the past two decades. Now, more than ever, the use of "trusted systems" is needed to ensure the secrecy, integrity, and availability of computer resources. However, attaining the levels of trust required has been difficult for a variety of reasons. This paper provides an in-depth look at the government's Trusted Computer System Evaluation Criteria (TCSEC) and its current applicability. An analysis of a military network running Windows NT version 3.51 as the network operating system is provided as a case study. The paper concludes with a discussion of the advantages and disadvantages of the TCSEC criterion. Although products have been certified as meeting the various class requirements, existing problems are preventing the attainment of "trusted" system from becoming a reality for many government organizations.

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DISCRETE ASYNCHRONOUS KALMAN FILTERING OF NAVIGATION DATA FOR THE PHOENIX AUTONOMOUS UNDERWATER VEHICLE

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The Phoenix Autonomous Underwater Vehicle must be able to accurately determine its position at all times. This requires: 1) GPS and differential GPS for surface navigation, 2) short baseline sonar ranging system for submerged navigation, and 3) mathematical modeling of position.

This thesis describes a method of Kalman filtering to merge the GPS, differential GPS, short baseline sonar ranging, and the mathematical model to produce a single state vector of vehicle position and ocean currents. The filter operates in the extended mode for processing the non-linear sonar ranges, and in normal mode for the linear GPS/DGPS data. This required installation of a GPS system and the determination of the different variances and errors between these systems.

Phoenix now has a real time method of position determination using either position measuring system separately or combined. The results of this work have been validated by real world testing of the vehicle at sea, where position estimates accurate to within several meters were obtained.

THE OBJECT-ORIENTED DATABASE AND PROCESSING OF ELECTRONIC WARFARE DATA

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Advisors: David K. Hsiao, Department of Computer Science

C. Thomas Wu, Department of Computer Science

The Electronic Warfare Integrated Reprogramming (EWIR) database is the primary Department of Defense source for technical parametric performance data on noncommunications emitters. It has been identified by the National Air Intelligence Center as difficult to use in its current hierarchical database form. There are two problems addressed by this thesis. First, is an object-oriented EWIR database a superior method for managing complex electronic warfare data collections? Second, is the prototype Object-Oriented Interface (O-OI) developed at the Laboratory for Database System Research in the Naval Postgraduate School capable of supporting a complex object-oriented database such as EWIR?

To answer these questions, a *subset* of the EWIR Object-Oriented Specification developed in a separate thesis is implemented on the O-OI. Using the O-OI Data Definition Language, the object-oriented EWIR database schema and its associated record data are stipulated and loaded to create the live database. Using the O-OI Data Manipulation Language, nine EWIR transactions are elaborated and executed.

The first result of this thesis is the O-OI performs as specified, but requires additional data manipulation and logical control functions to handle complex databases. The minimum additional functions include *Insert*, *Delete*, and *If-then-else*. The inheritance feature also requires a generalization-to-specialization data retrieval capability. The second result of this thesis is the straightforward data manipulation capability of the object-oriented version of the EWIR database. The object-oriented specification more accurately captures data relationships. The inheritance, path, and object comparison features streamline the linkage of related data, thus simplifying ad hoc query construction.

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PROTOTYPE SUPERVISORY AND SUMMARY DISPLAYS FOR THE ADVANCED TOMAHAWK WEAPON CONTROL SYSTEM (ATWCS)

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The problem addressed in this research is the need for supervisory or system summary displays for the Advanced Tomahawk Weapons Control System (ATWCS). These displays are needed to accurately depict the current system state and weapon status in order to aid strike supervisory personnel in making correct and timely decisions. This research examined the problem in the context of designing a set of graphical displays that extracts information relevant to the strike supervisor from ATWCS and displays it in a manner that allows both rapid and accurate interpretation.

The approach used to solve the problem progressed in four distinct phases. The first phase, Requirements Analysis, consisted of gathering system requirements through interviews with U.S. Navy officers who have experience as strike warfare supervisors. In the second phase, an initial design was produced using Century Computing's rapid prototyping tool TAE Plus Workbench™. The third phase involved the heuristic and guideline evaluation of the prototype based on accepted user interface design principles and ATWCS user interface requirement specifications. This evaluation produced a second iteration prototype that was used in the final phase, Usability Testing. The prototype was tested by U.S. Navy Officers with Tomahawk strike experience and test results were recorded. Changes were then made to the prototype to correct usability problems discovered by the user testing, yielding a third iteration prototype.

The final result of this research is a set of prototype displays, in both paper and TAE Plus Workbench™ resource file formats, that will be provided to Naval Command, Control, and Ocean Surveillance Center (NCCOSC) Research, Development, Test and Evaluation Division (NRaD) for consideration during system design and implementation.

AUTOMATED MESSAGING FOR THE GLOBAL COMMAND AND CONTROL SYSTEM: ANALYSIS OF UPGRADING COMMUNICATIONS IN THE NPS SECURE SYSTEMS TECHNOLOGY LABORATORY (SSTL)

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Carl R. Jones, Department of Systems Management

The Global Command and Control System (GCCS) is currently operational in the Secure Systems Technology Laboratory located in Root Hall at the Naval Postgraduate School. All subsystems of GCCS are operational with the exception of the Automated Message Handling System (AMHS). The SSTL's efforts to obtain an operational GCCS AMHS depends on the future availability of the Automated Defense Information Network (AUTODIN), and the emerging technology of the Defense Message System (DMS). This thesis examines and compares GCCS AMHS and DMS and the implementation requirements for each. This thesis draws the conclusion that DMS is the dominant system over GCCS AMHS and continues to examine the acquisition strategies and costs required to implement the DMS in the SSTL.

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AN ARCHITECTURAL MODEL FOR SOFTWARE COMPONENT SEARCH

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An important problem in the software development process is to make better use of software libraries by improving the search and retrieval process, that is, by making it easier to find the few components you may want among the many you do not want. The problem with the current production approaches is that they do not consider the behavior of components as a part of the retrieval process. As a result, it is impossible to obtain high recall and precision. In contrast, research approaches using syntactic and specification can be used to improve upon recall and precision. However, these approaches require a lot more computational effort. Without a library structure to support a retrieval process, they would be impractical. This dissertation concentrates on two themes. First, how to provide efficient and effective retrieval capabilities and an interactive friendly interface to support users to search for software components. Second, how to construct a library that can assist the librarian with cataloging software components and help to facilitate the search process. The first prototype has been implemented to verify the proposed ideas. Several studies have been performed to measure the system performance. The result confirms and strongly supports the proposed ideas.

POPULATING THE SOFTWARE DATABASE

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The cost of software development could be reduced if relevant reusable software components could be retrieved efficiently. The few libraries currently in existence have no standard method for selecting components germane to the intended application. This thesis focuses on the actual formation and population of library components for an improved software library model proposed in [Ref. 1]. This library would provide the codes for users to implement the desired system in CAPS environment.

The work reported here consists of: identifying candidate reusable components from the Booch Ada Library—by manually inspecting over 500 components; converting the components into a CAPS-compatible format based on the Prototyping System Description Language (PSDL) via Ada-PSDL converter program; creating algebraic specifications to match the semantic description of each component manually; and manually organizing the library into a data structure based on the multi-level filtering concept.

This work provides: (1) the base and guidelines for the: (a) criteria for a reusable component, and (b) process of inspecting and importing components into CAPS reusable component library, and (2) 75 reusable components to be released with CAPS 95 and used to test the user interface for retrieval via multi-level filtering. The process of populating reusable components is time intensive due to various manual processes. Inspecting and converting each component sometimes takes up to an hour for each. Current tools available can be rewritten, i.e., the PSDL-Ada converter, to fully automate this process in accordance with the base and guidelines.

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SIMULATION AND ANALYSIS OF A WIRELESS MAC PROTOCOL: MACAW

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MACAW (Medium Access Collision Avoidance Wireless) is a new MAC protocol for wireless LANs proposed by Bharghavan et al. [Ref. 2] based on Karn's MACA protocol [Ref.3]. In this thesis the performance characteristics and operational behavior of the protocol are investigated.

The approach taken was to simulate the protocol by OPNET 2.4c of MIL3, Inc. and determine the utilizations and mean delay times of the transmitters under various operational conditions. Also a new performance measure was defined in terms of utilization and mean delay time.

Our investigation has shown that the optimum performance of the MACAW protocol occurs at approximately 50% channel load. We have also shown the importance of the backoff algorithm, and finally, we have shown that carrier sensing dramatically improves the performance of the protocol for high channel loads.

Simulation results showed that decreasing the backoff increase rate by 15% gave twice as good performance results for the small number of transmitting nodes cases. When carrier sensing was introduced to the protocol, dramatic performance increases resulted under heavy loads (60% to 80% channel loads). Carrier sensing also pushed the optimum performance channel load threshold from 50% to 60%.

A TYPE INFERENCE ALGORITHM AND TRANSITION SEMANTICS FOR POLYMORPHIC C

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In an attempt to bring the ML-style type inference to the C programming language, Smith and Volpano developed a type system for a dialect of C, called PolyC [SmV96a] [SmV95b]. PolyC extends C with ML-style polymorphism and a limited form of higher-order function.

Smith and Volpano proved a type soundness theorem that basically says that evaluation of a well-typed PolyC program cannot fail due to a type mismatch. The type soundness proof is based on an operational characterization of a special kind of semantic formulation called a natural semantics. This thesis presents an alternative semantic formulation, called a transition semantics, that could be used in place of the natural semantics to prove type soundness. The primary advantage of the transition semantics is that it eliminates the extra operational level, but the disadvantage is that it consists of many more evaluation rules than the natural semantics. Thus it is unclear whether it is a suitable alternative to the two-level approach of Smith and Volpano.

Further, the thesis gives the first full type inference algorithm for the type system of PolyC. Despite implicit variable dereferencing found in PolyC, the algorithm turns out to be a rather straightforward extension of Damas and Milner's algorithm *W* for functional languages [DaM82]. The algorithm has been implemented as an attribute grammar in Grammatech's SSL and a complete source code listing is given in the Appendix.

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RESEARCH ON MOTION PLANNING OF AUTONOMOUS MOBILE ROBOT

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The path planning algorithm in Yamabico is based on a variation of Dijkstra's algorithm which has time complexity of $O(n^2)$. This algorithm works well in a dynamic environment, but a faster algorithm, called the All-Pairs Minimum Cost Paths algorithm, works even faster, $O(1)$, in the case of a static environment.

The computational complexity of the All-Pairs algorithm is $O(n^3)$, but if we know all pairs in advance, that is, the environment is static, we can preprocess them in advance, and use table lookup instead of Dijkstra's algorithm. Thus, we implemented a table lookup version for the static case, and kept Dijkstra's algorithm for the dynamic case. This results in both speed and flexibility.

This thesis also investigated the Linear Fitting Algorithm for Sonar testing. Range and angle data, from sonar, was fit to a straight line, giving resolution of 1 to 2.5 cm when the robot is within 100 to 150 cm of the line.

A REAL-TIME IMAGE UNDERSTANDING SYSTEM FOR AN AUTONOMOUS ROBOT

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Yamabico-11 is an autonomous mobile robot used as a research platform with one area in image understanding. Previous work focused on edge detection analysis on a Silicon Graphics Iris (SGI) workstation with no method for implementation on the robot. *Yamabico-11* does not have an on-board image processing capability to detect straight edges in a grayscale image and a method for allowing the user to analyze the data.

The approach taken for system development is partly based on edge extraction and line fitting algorithms of [PET92] with a 3-D geometric model of the robot's world [STE92]. Image grabbing routines of [KIS95] were used to capture images with the robot's digital output camera and processed using image understanding routines developed for a SGI workstation. The routines were modified and ported onto the robot.

The new method of edge extraction produces less ambient noise and more continuous vertical line segments in the gradient image which enhances pattern matching analysis of the image. *Yamabico-11*'s computer system can capture an image with a resolution of 739 x 484 active picture elements. Edge detection analysis is performed on the robot which generates a list structure of edges and stored in the robot's memory for user analysis.

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REACTIVATION OF THE RELATIONAL INTERFACE IN M²DBMS AND IMPLEMENTATION OF THE EWIR DATABASE

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and

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The primary Department of Defense source for technical parametric performance data on non-communications emitters is the Electronic Warfare Reprogramming Database (EWIRDB). Data representation in the EWIRDB is via disjointed parametric tree models which are implementation oriented. These parametric trees obscure the intended semantics and representation of the data, making the database difficult to use and understand. The problem addressed by this thesis is to determine if the relational model and the relational interface of the Multimodel and Multilingual Database System (M²DBMS) in the Laboratory for Database Systems Research at the Naval Postgraduate School is capable of supporting a representative subset of the EWIRDB.

We implemented a representative portion of the EWIR database on the relational interface of the M²DBMS. In order to accomplish this the relational interface was reactivated and returned to its original operational state and fully tested to determine its capabilities. In addition, the schema and an instance of a relational EWIR data model must be developed for implementation.

The relational interface was successfully returned to its original operational state. Significant limitations in the interface's ability to process queries were discovered, however, in that the system can not query schema of greater than four relations.

DESIGN AND IMPLEMENTATION OF REAL-TIME MONITOR FOR THE OBJECT-ORIENTED INTERFACE

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In a stand-alone database management system (DBMS), one of the key components is the real-time monitor (RTM) which handles database accesses and responses at run time. In the Multimodel, Multilingual and Multibackend Database Management System (M²DBMS) developed at the Laboratory for Database System Research in the Naval Postgraduate School, there is also the need of a RTM in order to link a specific Data Model and Data Language Interface to the Kernel DBMS. The problem addressed by this thesis is to design and implement a RTM for the Object-Oriented Interface to M²DBMS.

In this interface each object-oriented (OO) query is converted into the equivalent Attribute-Based Data Language (ABDL) queries. However, due to the complexity of the OO operations there is no way to produce these ABDL queries in complete and executable forms. Much of the information needed for the completion and execution of the ABDL queries is provided by the previous ABDL queries. The approach was to develop a RTM which oversees the execution of previous ABDL queries, receives the intermediate results from these queries, and completes the subsequent ABDL queries for execution in the Kernel.

The result of this thesis is a RTM which executes the OO query as directed by the compiler of object-oriented data manipulation language (OODML). Once the OO query is parsed by the OODML compiler, it is transformed into the equivalent ABDL queries and a series of pseudocode in compliance with the protocol between the OODML compiler

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and the RTM. The RTM executes the operations specified by the pseudocode by using its built-in functions. However, for the execution of the ABDL queries, it communicates with the Kernel DBMS.

FILE TRANSFER WITH SNR HIGH-SPEED TRANSPORT PROTOCOL

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To validate SNR as a high speed transport protocol, efficient means of transferring large data files are required. The problem is that no file transfer program is currently implemented for SNR. The SNR protocol was described in IEEE Transactions on Communications 91 Vol. 38 #11.

The approach taken was to modify the Trivial File Transfer Protocol (TFTP) and use it with the SNR Receiver and Transmitter implementations in both the FDDI and Ethernet LANs. The program was developed on top of the IP layer in the UNIX operating system using the C programming language. The UNIX system features that were adopted for this implementation were multitasking, shared memory, raw sockets and process control. This required overcoming the problems as signal loss, shared memory size, conflicts among the raw sockets and network interface configuration in an IP host.

The results were a fully functioning TFTP code for a modified SNR Transmitter and Receiver code and a new scheme in transferring files with SNR. An artifact of this thesis was that both client and server were single CPU running eleven processes each for file transfers. Due to this constraint, a large amount of latency in file transfer times, compared to Internet Protocol FTP, was observed.

SIMULATION-BASED VALIDATION OF NAVIGATION FILTER SOFTWARE FOR A SHALLOW WATER AUV NAVIGATION SYSTEM (SANS)

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Navigation filter software is currently being developed for an inertial navigation system without rotating gyros. This system shall replace the navigation system that is currently used in the Phoenix Autonomous Underwater Vehicle of the Naval Postgraduate School. The filter combines acceleration sensors, angular rate sensors, a water speed sensor, a magnetic compass and a GPS system. The harmonization of the sensors is performed by gain matrices. The filter code must be tested for correctness and evaluated, and optimal values for the gain matrices must be found. Both factors directly influence the accuracy of the computed positions, and thus the quality of AUV navigation.

In this thesis, the Kalman filter code is tested by experimentation with a simulation of a submarine. Two versions of the code are available, both written in LISP and C++. Test runs are performed in different simulated sea-states (water current), with and without noise added to the sensors, and with different values for the gain matrices.

Based on the experiments, the Kalman filter code seems to be correct and stable. Noise is the most important determinant of the filter performance. The results can be optimized by careful fine tuning of the gain matrices.

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MOUNTING HUMAN ENTITIES TO CONTROL AND INTERACT WITH NETWORKED SHIP ENTITIES IN A VIRTUAL ENVIRONMENT

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This thesis research addresses the problem of mounting human entities to other nonhuman entities in the virtual environment. Previous human entities were exercised as individual entities in the virtual environment. Yet there are many applications (i.e., shipboard damage control, amphibious landings, helicopter vertical assaults) where human entities need to mount other vehicles within the virtual environment.

The approach taken was to re-engineer the Naval Postgraduate School's Shiphhandling Training Simulator (SHIPSIM) and Damage Control Virtual Environment Trainer (DC VET) onto a common virtual environment system (NPSNET). Using a modified potentially visible set algorithm, a ship hydrodynamics model, and a simple data PDU network packet, NPSNET human entities were given the capability to mount ship vehicles. Additionally, a control panel and voice recognition were added to allow the human entities to control and maneuver the ship vehicles in the virtual environment.

As a result of this thesis, NPSNET human entities can mount ship vehicles, move about the ship, and interact with the ship's internal objects (i.e., doors, valves, etc.) all while the ship moves within the virtual environment. This technology opens a new paradigm for simulation designers, where users of virtual environment systems can participate as human entities and interact (i.e., mount, control, and maneuver) with other inanimate vehicles as we do in the real world.

A RAPIDLY RECONFIGURABLE, APPLICATION LAYER, VIRTUAL ENVIRONMENT NETWORK PROTOCOL

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The current Distributed Interactive Simulations (DIS) Protocol has a limited ability to support real-time, simulated engagements of more than 1000 entities because of its excessive use of network resources. It also lacks the extensibility to add new protocol data units to support new simulation requirements. To solve these problems it is necessary to design and implement a rapidly reconfigurable network protocol that can be easily changed and distributed to all entities in a large-scale simulation. This protocol must be highly flexible and allow for the optimization of data content during execution.

The approach used was to design and build a rapidly reconfigurable network protocol and the tools necessary to use it. This was accomplished in four phases. First, a protocol using the concepts of Self-defined Messages with Multiple Presentations was developed. Second, a formal grammar to describe the protocol was designed. Third, an existing protocol development tool, the DIS Protocol Support Utility, was modified to use the new protocol and grammar. Fourth, the protocol was tested to determine its effect on network resource utilization.

As a result of this effort, a network protocol for distributed simulations that can be optimized at run-time and easily modified has been developed. Testing shows that the protocol can reduce the network bandwidth necessary for a large-scale distributed simulation by up to 70%.

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INTERNETWORKING: MULTICAST AND ATM NETWORK PREREQUISITES FOR DISTANCE LEARNING

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The Internet, the World Wide Web and the Multicast Backbone (MBone) have been used in a variety of ways for distance learning. Video TeleConferencing (VTC) classrooms have obvious value and utility but they are limited to communicate with only a small number of similar VTC facilities. We are most interested in open solutions which take advantage of the global Internet. Therefore the problem addressed by this thesis is to evaluate the specific benefits and drawbacks of Internet technologies in support of distance learning.

This thesis includes a detailed examination of MBone, Asynchronous Transfer Mode (ATM) and the Distributed Interactive Simulation (DIS) protocol from the perspective of distance learning.

One result we found is that MBone can be used successfully for distance learning purposes despite common constraints of limited (128 Kbps) bandwidth. A further result is that an MBone classroom can be 42% as expensive as a VTC classroom if an *SGI Indy* is used and 12% as expensive as a VTC classroom if a PC is used in the classroom. Consequently many schools can afford Internet-based distance learning using the solutions presented in this thesis even though they cannot afford VTC rooms.

NEW MOTION PLANNING AND REAL-TIME LOCALIZATION METHODS USING PROXIMITY FOR AUTONOMOUS MOBILE ROBOTS

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One of the most difficult theoretical problems in robotics—motion planning for rigid body robots must be solved before a robot can perform real-world tasks such as mine searching and processing. This dissertation proposes a new motion planning algorithm for an autonomous robot, as well as the method and results of implementing this algorithm on a real vehicle.

This dissertation addresses the problem of safely navigating an autonomous vehicle through free space of a two dimensional, world model with polygonal obstacles from a start configuration (position/orientation) to a goal configuration using smooth motion under the structure of a layered motion planning approach. The approach proposes several new concepts, including *v-edges* and *directed v-edges*, and divides the motion planning problem of a rigid body vehicle into two subproblems: (i) finding a global path using Voronoi diagrams and for a given start and goal configurations planning an optimal global path; the planned path is a sequence of directed *v-edges*, (ii) planning a local motion from the start configuration, using the aforementioned global path. The problem of how to design a safe and smooth path, is effectively solved by the steering function method and proximity. Another problem addressed here is how to make a smooth transition when the vehicle gets closer to an intersection of two distinct boundaries.

This dissertation also presents a robust algorithm for the vehicle to continually eliminate its positional uncertainty while executing missions. This functionality is called *self-localization* which is an essential component of model-based navigation for indoor applications. This algorithm is based on the two-dimensional transformation group. Through this method, the robot can minimize its positional uncertainty, make safe and reliable motions, and perform useful tasks in a partially known world.

All of the proposed algorithms were implemented on an autonomous mobile robot *Yamabico-11* to confirm our analytical results.

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DESIGN AND EVALUATION OF AN INTEGRATED, SELF-CONTAINED GPS/ INS SHALLOW-WATER AUV NAVIGATION SYSTEM (SANS)

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The main problem addressed by this research is to find an alternative to the use of large and/or expensive equipment required by conventional navigation systems to accurately determine the position of an Autonomous Underwater Vehicle (AUV) during all phases of an underwater search or mapping mission.

The approach taken was to advance an existing integrated navigation system prototype which combines Global Positioning System (GPS), Inertial Measurement Unit (IMU), water speed, and heading information using Kalman filtering techniques. The hardware and software architecture of the prototype system were advanced to a level such that it is completely self-contained in a relatively small, lightweight package capable of on-board processing of sensor data and outputting updated position fixes at a rate of 10 Hz; an improvement from the 5 Hz rate delivered by the prototype. The major changes to the preceding prototype implemented by this research were to install an on-board processor to locally process sensor outputs, and improve upon the analog filter and voltage regulation circuitry.

Preliminary test results indicate the newly designed SANS provides a 100% performance improvement over the previous prototype. It now delivers a 10 Hz update rate, and increased accuracy due to the improved analog filter and the higher sampling rate provided by the processor.

THE ACTIVATION AND TESTING OF THE NETWORK CODASYL-DML INTERFACE OF THE M2DBMS USING THE EWIR DATABASE

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The Electronic Warfare Integrated Reprogramming Database (EWIRDB) is the primary Department of Defense source for technical parametric performance data on noncommunications emitters. A problem of the EWIRDB is that the data are represented in disjoint parametric tree models that are implementation oriented. The parametric tree with its deceptive hierarchical structure, provides a poor modeling construct that obscures the intended semantics and representation of the data, thus making the database difficult to use and understand from a users perspective. The problem addressed by this thesis is to determine if the network model and the network interface of the Multi-Lingual, Multi-Model Database Management System (M²DBMS) in the Laboratory for Database Systems Research at the Naval Postgraduate School is capable of supporting a representative subset of the EWIRDB.

The primary goal of this thesis is to implement a representative portion of the EWIR database on the network interface of the M²DBMS. In order to accomplish this goal, the following issues must be addressed: First, the network interface must be activated and returned to its original operational state; second, the network interface must be tested to determine its capabilities and limitations; and last, the design and specification of a network EWIR data model must be completed prior to its implementation.

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We successfully reactivated the network interface to its original operational state. However, testing revealed significant limitations of the network interface. Due to these limitations, only the data definition portion of our proposed design was fully implemented.

SOFTWARE SYSTEM REQUIREMENTS FOR THE ARMY TACTICAL MISSILE SYSTEM (ATACMS) END-TO-END SYSTEM USING THE COMPUTER AIDED PROTOTYPING SYSTEM(CAPS) MULTI-FILE APPROACH

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The Department of Defense (DoD) is seeking software system requirements for the Army Tactical Missile System (ATACMS) End-to-End System, which comprises both ATACMS and all sensors, links, and command centers which enable integration across system and service boundaries. The complexity, multiple interfaces, and joint nature of planned ATACMS operations demands accurate specification of software system requirements. DoD also desires automated tools capable of developing rapid prototypes to assist in system definition and reduce system risk.

The goals of this thesis are to provide a rigorous model which can be utilized to validate current specifications, and, to demonstrate CAPS on a large scale project. Accomplishment of these two would provide a needed corroboration of the ATACMS specification, as well as move CAPS out of the purely academic environment.

The result of this thesis is mixed. Due to a paucity of data from which to derive the requirements, the model is generic in nature and is in need of significant customer evaluation, which is not forthcoming. However, CAPS demonstrated its fundamental concept within the bounds of the project, with refinements in code generation, interface, and graphics either incorporated or identified. CAPS is ready for use on an actual project by an experienced team of systems analysts.

A METHODOLOGY FOR EVALUATING THE CAPABILITY OF THE BRADLEY 25MM CANNON TO ENGAGE AND DEFEAT PIONEER CLASS UNMANNED AERIAL VEHICLES.

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Unmanned Aerial Vehicles (UAVs) represent a serious threat to forward deployed forces of the United States Army. The defense against such threats is currently provided primarily by the Bradley Stinger Fighting Vehicle (BSFV). The problem addressed is how to evaluate the effectiveness of the BSFV against a UAV. This thesis develops a computer simulation methodology for modeling the capability of a gun system to engage a UAV. Specifically, a review is made of the BSFV, BSFV 25mm Ammunition, and UAVs. These reviews formed the basis for a computer simulation, coded in Common Lisp Object System (CLOS), modeling the characteristics of three objects: a Projectile, a Launcher and a UAV. Although assumptions were made to simplify the model, simulation runs demonstrated that the rate of fire and aiming system used for launching projectiles resulted in one or more hits in 125 out of 154 engagement sequences. These engagement sequences were against a UAV flying at constant speed and altitude in crossing and inbound/out-

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bound flight profiles. While all data used in this simulation were unclassified, the methodology presented could be used for further classified study, potentially producing a lower cost means for determining the effectiveness of air defense weapons against UAV threats.

**A GRAPHIC USER INTERFACE FOR RAPID
INTEGRATION OF STEGANOGRAPHY SOFTWARE**
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Master of Science in Computer Science-March 1996
Advisors: Cynthia E. Irvine, Department of Computer Science
Michael J. Zyda, Department of Computer Science

Steganography is a method an individual uses to secretly communicate, whereby the transmitting agent hides a message within some medium, so that only an intended recipient can detect the message's presence. Researchers who apply this methodology to digital imagery currently have no X Windows-based graphic user interface software package through which they may aggregate, test, and demonstrate their steganography programs. Such a package would contain features to encode data to and extract data from digital imagery, convert the files to other graphic file formats, display imagery, and offer some utility to analyze change between unencoded original images and their encoded equivalent. The steganography software development package presented in this thesis, named Steganography Toolbox, satisfies these requirements. It provides the above described features, plus the ability to delete unneeded files, all in an X Windows graphic user interface. It permits the user, who writes a separately executable steganography program, to attach it to the graphic interface with little additional programming effort. The thesis describes a method to create a menu-selected dialog box containing the necessary widgets, which invokes the desired program through a *system()* call. The thesis includes Steganography Toolbox's structured design documentation, from system requirements to process specifications. The thesis also describes how requirements-based software tests were performed on each module to verify proper function and error-handling.

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